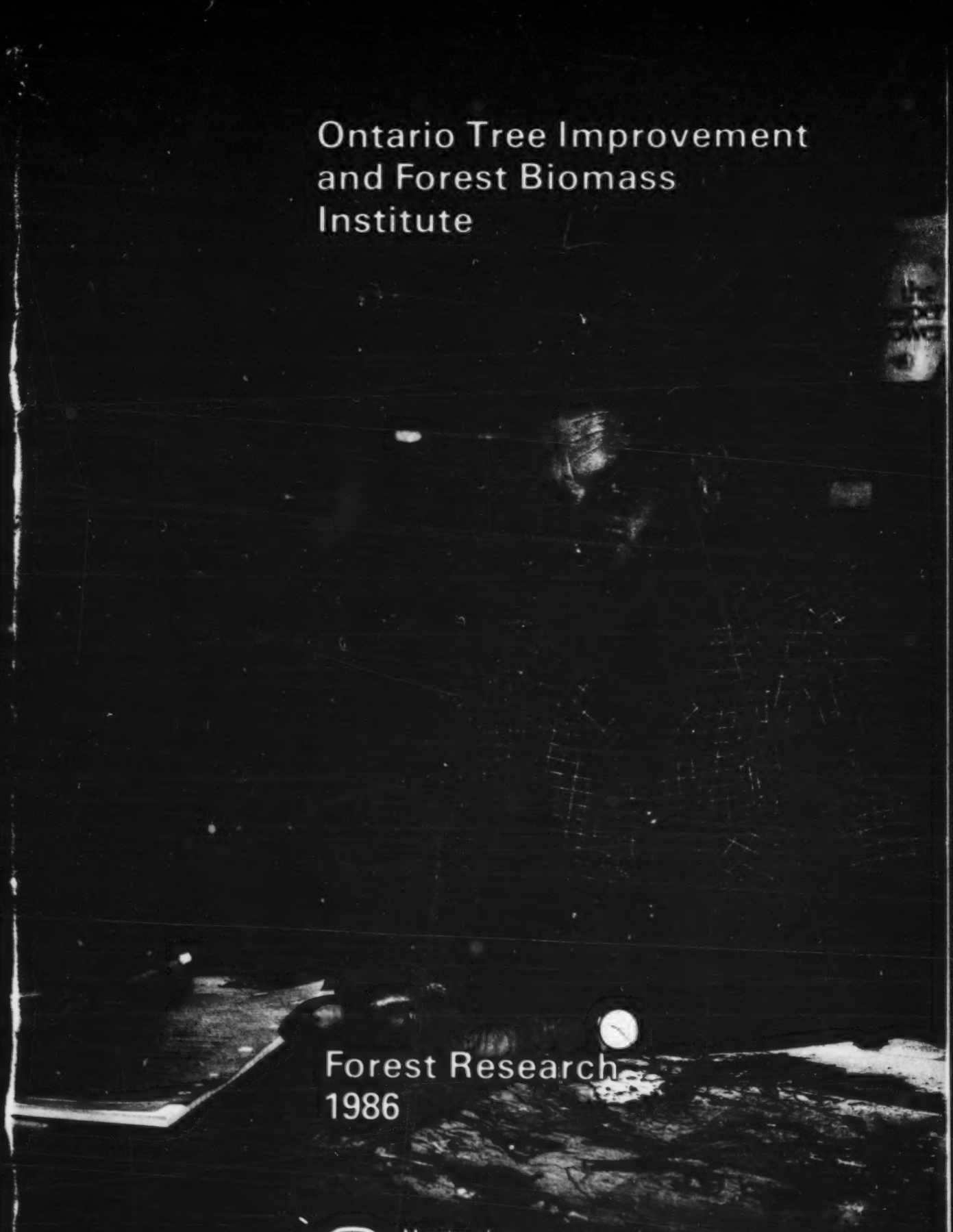
Ontario Tree Improvement and Forest Biomass Institute



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INTRODUCTION

Forestry in Ontario is on the move—literally as well as figuratively. The trend to work intensively managed forests on prime sites and in strategic locations is nov well established and expanding rapidly. We have an unprecedented capability to produce quality nursery stock to regenerate these areas.

In order to better serve the managers of these forests, the Forest Resources Group, including the Ontario Tree Improvement and Forest Biomass Institute, will be relocating to new facilities in Sault Ste. Marie. While such a move will be traumatic for some, who for whatever reason will be unable to relocate, it provides the best opportunity for expanded forest research activity that Ontario has ever seen. The prospect of state-of-the-art laboratories and ancillary greenhouses, nursery, and arboreta facilities can't help but excite the vigorous forestry scientists that we so badly need if we are to get the best possible value for money.

Intensive forest management costs money, and the "green thumb" management techniques so often practiced in the past are simply not good enough for the future. We need to know precisely what to do and when to do it to obtain a predictable result. That is what forestry is all about, and that is what OTIFBI is all about.

D.P. Drysdale
General Manager
OTIFBI

TREE IMPROVEMENT

Physiological Genetics

Growth Analysis of Jack Pine Container Stock

Two genetic test plantations were established in 1984 to determine whether or not population substructuring was discernable in terms of differential growth of jack pine population collections from a portion of Northern Ontario. Due to size limitations of production facilities, two types of stock were produced. Half the stock were grown in Ray Leach Super Cells in a greenhouse in 1983, overwintered in a shadehouse, and outplanted in June 1984. The remainder were sown in the same container type in winter 1984 and hardened off for planting in June 1984. Concern for performance of stock types and how they affect expression of heritable differences led to a continuing analysis of growth comparisons between stock types, between plantation sites, and among seed sources. At the more southern, Blind River site, overwintered stock from Blind River District sources were about 50% taller than current-year stock after the first growing season. By the end of the second growing season, this difference had dropped to 13%. The average height differential between stock types remained at about 4 cm over both growing seasons. Overwintered stock of Chapleau District origin was about 66% taller than current-year stock of the same origin after the first growing season; after the second season, this differential dropped to 17%. The average height differential between current-year and overwintered stock was 5 cm after both growing seasons.

Terry Taylor

Stock type performance at the Chapleau site was identical to that at Blind River at the end of the first growing season. However, at the end of the second season, the change in relative height between stock types was more pronounced at this northern site than in Blind River District. Overwintered stock was 28% to 30% taller than current-year stock, resulting in a 6 cm to 7 cm height differential. The expected source x plantation x stock type interaction will be examined in the future to help explain phenotypic variation present in the tests.

(G. Buchert and T. Taylor)

Multiple Site Testing of Selected White Pine Clones

Numerous white pine genetic tests have been established over the last four decades. Differing in experimental design, replication over different sites, and origin of material, these plantations are valuable for selection and further testing. The very best individual trees are currently being selected, grafted and outplanted into long-term test areas across Southern Ontario in standard replicated designs. In 1986,

30 clonal selections from Pakistan sources of Pinus griffithii included in a 1979 IUFRO trial were established at the multiple testing experimental sites. These selections exhibited winter hardiness and blister rust resistance. In addition, six selections from a 1975 weevil resistance experiment were grafted in 1986 for addition to the multiple site testing program. Three of these clones exhibited from 12% to 25% weeviling, while the remaining three showed no signs of weevil damage over the 10-year period to 1987. Selections for the 1987 grafting program include clones of P. albicaulis, P. flexilis, P. peuce, P. strobus, P. strobus x peuce, P. peuce x strobus, P. strobus x parviflora, P. parviflora x strobus, P. holfordiana x parviflora, P. monticola x parviflora, P. peuce x parviflora and P. flexilis x griffithii.

(G. Buchert and M. Weishar)

Isoenzyme analysis of black spruce needle tissue, demonstrated here by Karen Fischer, gives information on the genetic variation that exists between individuals in a population.

Testing White Pine for Blister Rust Resistance

Resistance to white pine blister rust by open-pollinated P. strobus families from the Orono rust-resistant seed orchard was initiated in 1986. Previous isozyme phenotyping of the orchard had permitted the identification and ramet-to-clone mapping of the orchard, so in December 1985, open-pollinated seed from 16 ramets representing seven orchard clones was sown in the greenhouse. Two bulk general collections were also included for comparison. One hundred seedlings from each source were inoculated with blister rust in September 1986 by placing an infected black currant cutting in each seedling container, making sure that maximum contact was made between the leaves of the currant and the needles of the pine. Beds were then covered with burlap and kept moist. After one week the currant cuttings were removed and the seedlings were moved to overwintering facilities. Analysis of needle-spotting data indicates quite different patterns of rate of disease development among the different clones and the bulk collections. Mortality is being monitored to determine the diagnostic value of levels of apparent infection within one year of inoculation.

(G. Buchert and M. Weishar)

Isozyme Studies

Black Spruce Clonal Identification

A COFRDA-supported project is under way to develop electrophoretic standards of isozyme variability in black spruce for identification of black spruce clones. Staff working on this project have developed a portable, standardized electrophoretic system; along with a comprehensive manual of procedures and training video now in preparation, this will allow personnel without extensive specialized training and specialized laboratory facilities to catalogue, identify and eventually certify black spruce clonal stocks. Isozyme analysis by electrophoresis enables one to discriminate accurately and consistently between materials of different clones by comparing samples with standardized isozyme patterns of specific clones. The equipment development phase has been completed, and procedures have been standardized to use a small inventory of inexpensive equipment. Chemical procedures have been optimized to yield useful information at relatively low cost. The manual of procedures and accompanying video will cover all aspects of the electrophoretic technique in sufficient detail that routine tests for identification, certification and quality control will become as commonplace in black spruce clonal production as they are for many agricultural crops.

(G. Buchert, K. Fischer and L. Farintosh)

Cone Induction

Enhancement of seed-cone production was achieved by spraying gibberellic acid 4/7 ($GA_4/_7$) onto foliage of black spruce (Picea mariana) growing in Glencairn seed orchard and in Allandale and Maple arboreta. The objectives were: i) to establish the optimal concentration of $GA_4/_7$ for bud differentiation by foliar spraying, ii) to investigate the effect of $GA_4/_7$ and vitamin E, and iii) to correlate bud development and shoot elongation with the timing of $GA_4/_7$ application.

Foliar Spraying in a Seed Orchard

Eighty trees representing 10 clones growing in the orchard were selected, and foliage above the third whorl from the terminal was thoroughly wetted using a fine mist sprayer with 0, 400, 800, or 1 200 mg/L of $GA_4/_7$ in a solution containing 20% ethanol and 0.05% Tween 20 surfactant from a week after vegetative bud burst in May to the end of June. The trees were sprayed weekly for a total of six times per tree. The cone crop was assessed the following year.

Trees sprayed with $GA_4/_7$ produced significantly more seed cones than those sprayed without $GA_4/_7$, although no significant difference was found among the three $GA_4/_7$ concentrations used. The controls produced an average of 130 seed cones per ramet, while trees sprayed with 400, 800, and 1 200 mg/L $GA_4/_7$ averaged 246, 235, and 283 seed cones per ramet, respectively. It appears that 400 mg/L $GA_4/_7$ is the optimal concentration for bud differentiation by foliar spraying onto field-grown black spruce.

(R.H. Ho)

Foliar Spraying in Arboreta

Four trees each of seven clones and four families were sprayed as described for the seed orchard in spraying technique, crown region and timing of spraying. The solutions were 0, 800 mg/L $GA_4/_7$, 1 000 mg/L vitamin E, and a combination of 800 mg/L $GA_4/_7$ and 1 000 mg/L vitamin E, each containing 20% ethanol and 0.05% Tween 20 surfactant.

Spraying with $GA_4/_7$ alone or in combination with vitamin E was effective in promoting production of seed cones, while spraying without $GA_4/_7$ or with vitamin E alone was not effective. Spraying with $GA_4/_7$ produced an average of 196 seed cones per tree, and a combination of $GA_4/_7$ and vitamin E produced 250 seed cones per tree. The controls averaged 74 seed cones per tree, and vitamin E spraying 53 seed cones per tree.

(R.H. Ho)

Bud Morphogenesis

Five seed-cone buds and five vegetative buds, five pollen-cone buds and five vegetative buds were sampled from the upper and lower crown, respectively, on each of 12 ramets, representing 10 clones. Bud burst, shoot elongation on the terminal of one of the first-order lateral shoots, and development of the current-year buds were also monitored for each ramet.

Seed-cone buds had significantly fewer bud scales than vegetative buds from the upper crown, and pollen-cone buds had fewer bud scales than either seed-cone buds or vegetative buds from both the upper and lower crown. Seed-cone buds averaged 48 bud scales per bud while pollen-cone buds averaged 36. Vegetative buds from the upper crown had 56 bud scales, while those from the lower crown had 49. Bud burst occurred in mid-May followed by four weeks of rapid shoot elongation. The elongation slowed down in mid-June and ended in late June. Leaf primordia began to be initiated on shoot apices at the end of June, and initiation continued until the beginning of September. Pollen-cone buds completed their microsporophyll initiation in mid-August. It appears that biochemical differentiation precedes bud-type differentiation, since genes signal the earlier termination of bud-scale initiation on reproductive buds and the switch to bract and microsporophyll initiation. Therefore, spraying before leaf primordium initiation would enhance seed-cone production.

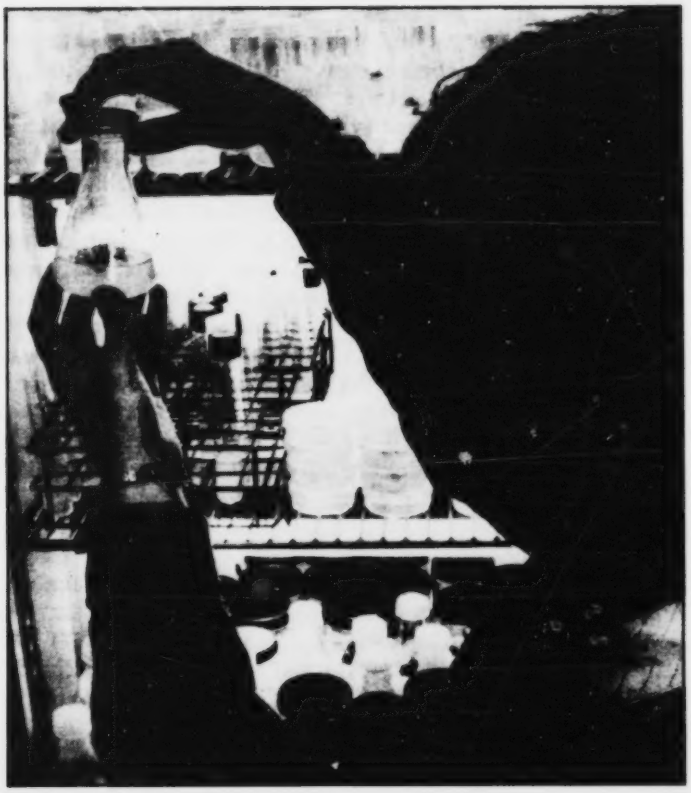
(R.H. Ho)

Biotechnology

There are two projects in biotechnology research: i) haploid plant induction in white poplar (Populus alba), and ii) in vitro culture of explants from black spruce and jack pine (Pinus banksiana). In haploid induction, plantlets will be raised from embryoids which are produced through anther culture, and isogenic pure lines will be selected for breeding. In explant culture, an in vitro technique will be developed to produce plantlets from explants of mature trees, and the plantlets will be examined for their juvenile characteristics. Rejuvenation through in vitro culture is desirable for mass propagation of superior genotypes which have been proven by progeny testing.

Haploid Plant Induction in White Poplar

Five clones growing in an arboretum at Maple were selected, and catkin buds were collected when pollen in the anthers had reached the mononucleate stage. Anthers were removed from the discs and sterilized in 10% Javex bleach solution for 15 minutes. Anthers were then incubated on Murashige and Skoog (MS) medium supplemented with one mg/L kinetin or a combination of one mg/L kinetin and 5 mg/L proline. The culture was placed in an incubator with a temperature of 25°C in darkness for about two months. When embryoids or calli were observed on anthers, the culture was transferred to a growth room with a 16-h photoperiod (30 uE/m^2/s) and temperature of 25°C during the day and 15°C at night.



Anne Baird examines a haploid plantlet induced by anther culture.

Embryoids were produced from two clones at a frequency of 0.3% when anthers were incubated on MS medium with kinetin. No embryoids were produced from the medium with kinetin and proline. Embryoids emerged from the anther cavity through the abscission layer in anthers and were globular in shape before developing the polarity of epicotyl and radicle. Some were found to have multiple cotyledons (three or more) and others had two. A few embryoids had a root with many root hairs. After the transfer to a growth room, some embryoids had germinated and produced shoots. However, there were no surviving plantlets for karyotype analysis because of low induction frequency and contamination.

In an analysis of pollen grains in anthers after six months of incubation, 92% of the pollen was found to be mononucleate or to have divided equally to produce mature pollen. Equal cell division occurred in about eight per cent, in which three per cent remained at the two-cell stage and five per cent divided further to produce multiple-cell pollen.

All the pollen grains showed signs of degeneration at the time of examination.

(R.H. Ho)

Explant Culture in Black Spruce and Jack Pine

Fifteen black spruce and five jack pine trees growing in the arboreta at Maple, Ontario, were selected for the study. The black spruce were of three age classes (15, 25, and 30 years old), while the jack pine trees were 25 and 30 years old.

Pre-treatment was carried out to prevent oxidation of explants before incubation. Twigs with dormant buds in black spruce were collected one day before incubation. The bud scales were removed from the buds, and the embryonic shoots were excised from the twigs either above or below the crown. They were soaked in various solutions with different antioxidants. The antioxidants were: one per cent ascorbic acid, one per cent activated charcoal, a combination of ascorbic acid and charcoal, one per cent butylated hydroxyanisole (BHA), one per cent butylated hydroxytoluene (BHT), 10% ethanol, and autoclaved distilled water. After the soaking, the embryonic shoots with or without crown were sterilized and incubated on MS medium supplemented with 10 mg/L benzylaminopurine (BAP) and 0.2 mg/L naphthaleneacetic acid (NAA) for three months. The culture was placed in a growth room with a 16-hour photoperiod (60 uE/m^2/s) and temperature of 25°C during the day and 15°C at night. It was found that embryonic shoots with crown grew best at 95% after soaking in one per cent activated charcoal or autoclaved distilled water; none survived after BHA pre-treatment.

A study was undertaken to define a suitable combination of cytokinin and auxin for culture of embryonic shoots in black spruce. Four media (1/2 MS, MS, 1/2 GD and GD) (GD, Gresshoff and Doy medium) were factored with four concentrations of BAP (0, 2, 5, and 10 mg/L) when NAA was at 0.01 mg/L, and the four media with five concentrations of NAA (0, 0.01, 0.1, 1, and 5 mg/L) when BAP was at 2 mg/L. The results showed that 5 mg/L BAP was best when 1/2 MS, GD and 1/2 GD each had 0.01 mg/L NAA, and 0.1 mg/L NAA was best when 1/2 MS, GD and 1/2 GD each had 2 mg/L BAP. Little or no growth was found when each of the four media was supplemented with 2 mg/L BAP and 5 mg/L NAA.

Adventitious shoots were regenerated from embryonic shoots of black spruce. Embryonic shoots with crown were cultured on six kinds of medium, each supplemented with 5 mg/L BAP and 0.2 mg/L NAA. The incubation period ranged from one to eight weeks before they were transferred onto a medium without any supplement. The media were MS, GD, LP (Quoirin and Lepoivre medium), SH (Schenk and Hildebrandt medium), WPM (woody plant medium) and LM (loblolly pine medium). It appeared that GD and LP were most suitable, and four weeks' treatment was optimal for black spruce. There were two modes of adventitious shoot regeneration: i) adventitious shoots were regenerated from the axillary area of leaf primordia on the embryonic shoots, and ii) adventitious shoots were redifferentiated from leaf primordia. The first mode was most common, and often many shoots were produced from an embryonic shoot. The second mode was observed occasionally, and the adventitious shoot primordia often produced shoots with thin stems. Many adventitious shoots had elongated to about 0.5 cm in height and could be excised for rooting to produce plantlets.

In jack pine, calli have been regenerated from young leaves and cross sections of long-shoot terminal buds, but no organogenesis has been observed in the calli. The media used and the supplements of growth regulators for the media were the same as described for black spruce. Long-shoot terminal buds, shoot tips, dwarf shoots, male-cone buds, and longitudinal and cross sections of the terminal buds were used for incubation after soaking and sterilization. SH and GD media appeared to be most suited for explant culture of jack pine.

(R.H. Ho & A.Y. Raj)

Hardwood Tree Improvement

Hybrid Poplar/Willow Minirotations

Establishment Methods:

As a result of the success of previous trials, which showed that high-density minirotations of hybrid poplar could be established efficiently using horizontal or flat-planted cuttings, two additional clonal trials were established in 1985. They were designed to demonstrate the technique and to further select clones valuable for their use-characteristics, which are also well-suited to the technique.

One of the plantings was established at Vespra, involving one-metre-long cuttings of 11 clones in three replications plus a vertical control. The plantation was cut back after the first growing season (1985) and the one-year coppice sampled in 1986. The plantation will be managed on a two-year cutting cycle, and biomass productivity will be determined after the 1987 growing season.

Survival of the one-year coppice "stools" was good, with seven of the clones showing 100% survival (NM-8; DTAC-1, NM-5; MD-1; DTAC-15; N-164; N-13). Two had 98% survival (TRI-16; NM-9), and only one clone had less than 60% survival (DTAC-17). Average heights were computed based on a sample of five dominant sprouts per cutting. The best clones in this respect were NM-5 (197.6 $\pm$12.8 cm), followed by NM-9 (172.76) and MD-1 (171.19). The worst clone was DTAC-17 (46.7 cm) which would have been affected by low survival, since the averages reflect the values per planted cutting (ie. a dead cutting would contribute five sprouts of 0 height). A similar order of ranking was observed for average basal diameter, with NM-5 showing the best growth (1.50 $\pm$0.12 cm).

These values compare favourably with the vertical controls, where only four of the 11 clones showed 100% survival (based on twice as many 25-cm cuttings). NM-8 was the best-growing vertically planted clone, averaging 167.3 cm dominant sprout height and 1.37 cm basal diameter.

The second trial was established at Maple and comprised two elements: i) a demonstration of the "cluster" configurations using clones considered well-adapted to the technique and ii) a trial of clones selected for their high energy characteristics. This plantation differed from most others in the programme since it was irrigated as necessary (in accordance with the surrounding nursery practice).

The cluster demonstration was established in similar fashion to that used for the Vespra planting (ie. one-metre-long cuttings planted horizontally in 4-cm-deep trenches, arranged in row-pairs 0.5 m apart,

the pairs separated by one-metre corridors). A guard row surrounded the planting. The sprouts were cut back after the first (1985) growing season, and the one-year coppices were sampled for growth at the end of the 1986 season. The plantations will be managed on a two-year cutting cycle.

At the end of the two years, there was no stool mortality in any of the four clones studied (MD-1, DM-2, NM-4, N-75). Average dominant sprout height for the one-year coppices (calculated from the five tallest sprouts per cutting) varied from 223.67 cm (NM-4) to 157.01 cm (DM-2) and average basal diameter ranged from 1.59 cm (NM-4) to 1.40 cm (N-75).

Of the eight clones planted in single rows (non-cluster arrangement) adjoining this demonstration, only two clones showed stool mortality (TRI-16, 95% survival) and (TAC-38, 90% survival). In terms of both average dominant sprout height and basal diameter, best clones were TAC-40 (147.38 and 1.50 cm) and TAC-24 (145.64 and 1.55 cm) respectively.

Other current trials to be harvested after the 1987 growing season include a horizontal (scatter) planting established in 1983 and managed on two-year rotation, a spacing/rotation trial of hybrid poplar (vertical planting) and a two-year willow minirotation (vertical planting).

Spacing/Clonal Studies

A hybrid poplar clonal spacing x rotation experiment was established using normal planting techniques at Vespra in 1983. It included five clones planted at three spacings (0.3 x 1.0, 0.6 x 1.0, 1.2 x 1.0 metres) managed on one-, two-, and three-year cutting cycles in an unbalanced incomplete block design. The planting was coppiced after the 1983 growing season. At the time of harvest after the 1985 growing season, in which one-year and two-year sprouts were harvested, performance was best for clones MD-1 and NM-6 (95.8%, 272 cm, 416 cm; and 95.8%, 234 cm, 420 cm respectively for survival, one-year height and two-year height).

The same two clones showed the best oven-dry productivity, although there was great variation among the replications which was only partly explained by differences in stool survival. On an annual basis, best average productivity was shown by NM-6 at 0.6 x 1.0 m on a two-year cycle (0.60 od $kg.m^{-2}.a^{-1}$).

A willow minirotation involving eight clones was established with vertically planted cuttings in spring 1983 at Vespra at 1 x 0.3 m spacing designed for a two-year cutting cycle. The plantation was coppiced after the 1983 growing season and the two-year sprouts were harvested after the 1985 growth. At that time, seven of the eight clones had stool survival in excess of 94%.

In terms of height ranking of dominant stem, the tallest clone was SAC-1 (389 cm) followed by SV-1 (332 cm) and SA-25 (322 cm). It is of interest that three clones put on more than 50% of their height growth during the second year (SA-25, SV-1, and SAC-1). These were all tree-form willows; the shrub-form willows tended to grow less in the second season. In terms of basal diameter, the biggest clone was SD-1 (2.37 cm), followed by SV-1 (2.20 cm). The clone with the largest number of sprouts per stool was SP-3 (11.0), followed by SH-3 (7.6). The fewest sprouts belonged to SAC-1 (3.1). An overall ranking system based on height, diameter and number of sprouts showed best composite score for SV-1, followed by SD-1 and SAC-1.

Biomass productivity was highest for SV-1 (1.925 od $kg.m^{-2}$ over two years) followed by SD-1 (1.563) and SH-3 (1.248).

(H.W. Anderson)

Black Locust Coppicing Study

In 1983, a black locust planting trial was established at Vespra at a spacing of 1.5 x 2.0 m with three stock sizes. After the 1983 growing season, it was decided to study coppicing behaviour and productivity performance at three cutting cycles. The original replicated design was split to accommodate three rotation lengths, and harvests were scheduled to include the 1983, 1984 and 1985 growing seasons. Thus, trees would be grown as seedlings for one, two or three years, then coppiced and continued on the appropriate cutting cycle.

Survival of the seedlings exceeded 99%. Analysis of variance indicated significant effects of original stock size on seedling biomass after one year ($P<0.01$), but not after two years. Similarly, stock size had no significant effect on subsequent one-year coppice productivity. The one-year coppice harvest for the 1984 and 1985 growing season had annual productivities of 0.295 and 0.262 od $kg.m^{-2}$ respectively.

The vigour of the coppices is considerable, and it is expected that the two-year and three-year coppice productivity will be substantially higher, since at 1.5 x 2.0 m spacing, the one-year coppices do not effectively utilize the growing space.

(H.W. Anderson and P. Jaciw)

Species Introduction and Improvement

Intensive forest management with extensive use of artifical regeneration exerts considerable genetic impact on almost every aspect of future forest stands.

Rapid advances in innovative genetic technology add appreciably to the evaluation of genetic gain by increasing selection differential and heritability of desirable characteristics within the preferred species. The work involves: i) establishment and maintenance of quality gene pools replicated over a wide range of physiographic conditions; ii) selection of desirable variants; and iii) development of methods of mass propagation using such techniques as cloning, layering, budding and grafting to lead to stock improvement and stand rehabilitation.

Work on species introduction, gene pool establishment and propagation techniques continued mainly on European locust, black alder, aspen hybrids and black walnut.

In 1986, we participated with the Districts, Regions and Conservation Authorities of Southern Ontario in the improvement, establishment and tending programs of the above-mentioned and associated species. A series of half-sib progeny have been assembled with a view to building up black walnut gene pools comprising northernmost selections of this rapidly depleting species. Scions have been derived from propagation stools developed for this purpose from quality phenotypes during preceding years. Fresh scions off stooling beds have almost immediately been grafted onto vigorous rootstock of matching size, attaining above-average "take" and vigour without special amelioration measures.

Hilling or deep planting of black walnut stock proved highly conducive to superior development of trees showing a prolific regeneration of fibrous feeder roots. In general, root pruning of stock of other hardwoods also proved highly advantageous to the propagation and general performance of some preferred hardwood species. Juvenile walnut severed at the ground level appears to retain an extraordinary capacity for coppicing and a strong regenerative potential, a basic prerequisite for "split-cloning" of this valuable species.

Seed of 19 select sources of black alder has been procured from free-pollinated clones of plus trees of Bavarian and Central European origin. The current collection was tested for germination and planted in February. The stock was greenhouse-grown in tubes and later raised and nursery-planted to be used for the enrichment of gene pools and for the improvement of stock on both upland and lowland sites, where it will contribute to repopulation of stands devastated by Dutch Elm disease. It will also be used to rehabilitate depleted upland sites, where as a nitrifying nurse crop it can add to yields and defray management costs early in the rotation.

European alder, a fast-growing, fine-quality species, exhibits a variety of industrial, ecological and other values including a wide tolerance of sites from below pH4 to pH8, tolerance of prolonged flooding and inundation, and exceptional resistance to diseases and animal pests.

Improvement work is also being carried out with black locust selections with a view to rehabilitating depleted alkaline site types and generating valuable products.

(P. Jaciw)

Breeding of Fast-Growing Poplar Hybrids

Hybrid Poplar Energy Survey

The hybrid poplar energy survey, funded by the Ministry of Energy for a five-year period starting in 1981, has been completed. This study, involving 140 clones of hybrid poplar (and small numbers of other genera such as alder, locust, willow, birch, maple), examined clonal variation in a large number of physical and chemical characteristics, including energy content.

Chemical analysis of both whole-stem tissue (wood, bark, pith, buds) and individual components using sequential extraction, HPLC and GC analysis indicated that energy differences were closely related to extractive content, both qualitatively and quantitatively. Most active of these components was the non-polar fraction, and good correlation was identified between energy levels and fatty-acid content.

Hybrids resulting from crosses guided by these findings, using high-biomass females and high-energy males, has resulted in selection of 25 individual offspring from three families which show promise. Average stool energy productivity in 1985 was midway between that of each parent. Based on productivity estimates for 1986, using regression equations developed from 1985 data applied to dimensional growth in 1986, superior individuals, if cloned, could have energy productivities of 600 $Gj.ha^{-1}.a^{-1}$, equivalent to 100 barrels of crude oil. These estimates are based on very small samples and will be verified by analyzing future

performance of clones being developed from the best of these superior individuals. A comprehensive report describing this entire project is in preparation.

(H.W. Anderson)

Aspen Clonal Study

Micro-organisms Associated with Defect

Results of attempts to isolate micro-organisms during the clonal study were entered on computer for analysis: i) to determine whether specific organisms were associated with specific types of defect, or whether their occurrence was random; ii) to determine whether pairs of organisms occur with less or greater frequency than random theory would predict, and iii) to investigate possible ecological significance of the occurence of pairs with respect to time, site, or differences in aspen clones. Analysis of the data will be undertaken in 1987.

Aspen Clones for a Clone Bank

Roots from individual trees were collected from single stands in the Kirkland Lake and Timmins Districts and a number of stands in the Thunder Bay District to serve as propagules for clonal multiplication. The study undertaken will: i) provide information on the plasticity of clonal phenotypes resulting from differences in regional climate and local site; ii) provide a replicated clonal study of native aspen; iii) provide material to study the variability of isozymes within and between known clones (considerable variability within putative clones was found in one study); and iv) determine the need to reserve selected clones in a clone bank. Approximately 4 000 trees were produced from the roots collected, to be outplanted during the spring of 1987. Three sites were prepared for the plantings, one in each of the aforementioned districts. In the Kirkland Lake and Timmins Districts, the prepared sites are within the stands from which the clones were taken.

(D.H.Weingartner)

Spruce

Spruce Hybridization

Following the massive spruce flowering year in Ontario in 1984, flowering in 1985 was light. Two breeding areas were used, one each in Sault Ste. Marie and Simcoe Districts. Eighty-five tree x pollen parent crosses were made with 115 ramets. Results of those crosses were evaluated early in 1986. There were 24 interspecific crosses involving 16 species; 12 tri-hybrid crosses, and one hybrid backcross, involving 14 species. Some of these were repeat crosses to gain repeatability estimates and to increase stocks of particular hybrids.

Emphasis continues to be placed on the search for fast-growing hybrids for use in the boreal forest. To this end, selections of high-latitude Sitka spruce (Picea sitchensis) were crossed with an array of white spruce (P. glauca) from Moosonee, Black Sturgeon, Pays Plat, Pembroke, and Lindsay. These crosses were, as expected, all successful, and the seed banked in storage until all required combinations are completed.

Similarly, high-latitude P. sitchensis were crossed with an array of black spruce (P. mariana) from Black Sturgeon, Geraldton, and Thunder Bay, Ontario, and Green River, New Brunswick. We have previously noted that black spruce remains stubbornly incompatible with many other spruce species. These crosses were no exception and were mostly unsuccessful. The very few seedlings will be added to those few produced in previous years, and when there are sufficient numbers, will be selected and cloned for outplanting. Despite low numbers of filled seed per cone in a few crosses, there were hardly any seedlings produced. This continues to demonstrate the uselessness of filled seed per cone as a measurement at critical levels in crossability studies.

Norbert Lussier in experimental spruce

Most other interspecific crosses were unsuccessful, but P. engelmannii was crossed successfully as a new-to-science cross with P. farreri, a high-elevation Burmese species, and P. omorika with P. jezoensis, both with low crossabilities. The hybrid seedlings will be cloned. It has been previously thought from our work and that of others that Serbian spruce (P. omorika) will cross with just about any species. Our data shows that this is definitely not true. In addition, the crossabilities which are obtained vary widely, depending on the other species, from great resistance to crossing, to almost total compatability. This phenomenon is also true of certain other species. These differences in crossabilities are of great use in determining evolutionary proximity of spruce species and complexes.

P. sitchensis was crossed successfully with P. jezoensis with a surprisingly high crossability of 14%. This is not a new cross, but the crossability was not expected to be so high. This confirms the close relationship of these species as suggested by some British workers.

Tri-hybrid crosses involving P. x lutzii (P. sitchensis x P. glauca) were successful with P. glehnii, a Japanese species; P. likiangensis, a Chinese species; and P. omorika, with low to moderate crossabilities. They also crossed with red spruce (P. rubens) and black spruce (P. mariana), but with much lower crossabilities. Interestingly, P. x lutzii failed entirely to backcross with Sitka spruce (P. sitchensis), providing further evidence to confirm our earlier findings that backcrossing with several spruce hybrids is proving less successful than expected. This has important implications for arguments concerning casual introgression in spruce, and perhaps in other genera.

Progeny from two tri-hybrid and backcross experiments are currently rising in the nursery. They represent our rapidly growing P. omorika x P. rubens hybrids backcrossed to P. omorika and P. rubens, and outcrossed

to P. mariana in various combinations. Preliminary results suggest some backcrosses are also rapid growers. Others are inferior to F2 hybrids. These seedlings will be outplanted in one to two years.

(A.G. Gordon)

Growth Study in White Spruce

This was the second year of data collection for a white spruce shoot growth study. Growth patterns will be compared between and within families, between years, and to climatic conditions.

(L. Farintosh)

Black Spruce Wood Quality

A report on current literature concerning black spruce wood quality was prepared for the Ontario Tree Improvement Council.

(L. Farintosh)

Genetic Tests on Norway Spruce

Three Norway spruce genetic tests were established on each of three different sites in southern Ontario: in Brockville, Niagara and Owen Sound. The first experiment is a progeny test of Norway spruce clones currently present in various OTIFBI clone banks. The general and specific combining ability of these clones is being tested. The second experiment tests specific hybrid crosses between Norway and other spruce species. For the third experiment, seed was collected from the better Norway spruce plantations in southern Ontario. The resulting progeny will be used to assess which of these plantations would make the best seed collection and seed production areas.

(L. Farintosh and J. Wild)

Norway Spruce Breeding Orchard

The management plan for the Norway spruce breeding orchard to be established at Orono nursery in 1988 was written this year. Controlled crosses will be performed in the orchard as soon as it flowers. The resulting seed will be used to produce rooted cuttings for progeny tests and production plantations.

(L. Farintosh and J. Wild)

SEED RESEARCH

Seed Utilization in Stock Production Systems

Black Spruce Accelerated Transplants

The final project in a long series of studies of pregermination techniques in the production of accelerated transplants was assessed and the series terminated.

The studies were initiated as part of a seed research program to improve seed utilization, reduce nursery stock variability (thereby reducing culling), and maximize early vigour of stock, particularly for greenhouse systems. Earlier projects investigated seed sorting techniques, time of germination and pregermination systems. Pilot

operations were conducted at Swastika nursery using peat cubes as containers. A large media/systems trial followed, which prompted a comprehensive feasibility study involving cost comparisons of various systems. As costs were related directly to greenhouse stocking, further work on mini- and micro-containers was recommended.

The final projects were in response to the Ernst and Whinney Report recommending further study of mini- and micro-stock production systems. Their goal was to determine the potential for developing bare-root black spruce transplants in a range of container sizes and types, in both one- and two-transplant systems.

Earlier work at Midhurst had shown the two-transplant system had an advantage over direct transplanting of mini-container stock of the same age. A 1982 project compared Choroplast container and cigarette-plug-grown black spruce, summer-sown, overwintered, then either transplanted into cubes or maintained in their original containers before transplanting. Larger initial stock was produced in germination plugs (larger containers and lower density in the greenhouse) than in Choroplast containers. More vigorous growth occurred with stock transplanted as a peat cube than with direct-transplant stock.

In April 1984, a small trial was established with seed sown in cigarette germination plugs and planted in peat cubes after seven weeks. Stock was grown in containers for the remainder of the season and overwintered. The container stock was transplanted in the spring of 1985 at Midhurst and sampled in the fall of 1985. Though results were encouraging, the expected standards were not achieved.

The second trial was sown in July 1984 at Maple in Choroplast, cigarette plug, Castle and Cook (1/2" and 3/4"), Ontario tubes, Dewa blocks, and Japanese paperpots (105 and 205). Stock was overwintered in original containers at Maple and transplanted at Swastika Forest Station on June 3, 1985. Due to losses in the greenhouse, the Castle and Cook 1/2" containers produced inadequate numbers to continue. As with Midhurst, none of the summer-sown overwintered container stock achieved an adequate-sized one-year shippable plant. Plant size after one and two years in transplant beds was related less to the type than to the size of container in which the seed was sown. Initial growth was restricted in smaller containers, and subsequent nursery growth reflected that initial loss in vigour. As in earlier studies, acceptable two-year-old accelerated transplants (ie. plants over 5 g) were achieved only in Dewa blocks and Ontario tubes.

Following the feasibility study, Thunder Bay Forest Station moved directly into large-scale development of Castle and Cook mini-container accelerated transplants. Currently they are producing acceptable G+1 shipping stock and even better overwintered G+1 black spruce. It is probable that each mini-season could be similarly developed.

(D.A. Skeates)

Container Stock

Interest has been shown by one of the northern growers in the use of cigarette germination plugs in container production. In cooperation with Evergreen Enterprises and with support from the Northern Region, MNR, a pilot project was initiated. Five thousand plugs were sown at Maple in February and grown for a month before transplanting into peat cube and paperpot containers at Raymore.

The interest in pregermination technology related to ensuring high stocking in the greenhouse, along with saving a month of greenhouse time, as the germination process requires only 15% of the space of container stock. Germination plugs also offer an advantage as a refill system using stock of the same age and size as achieved in normally sown trays of containers. For multiple cropping systems, the use of germination plugs grown concurrently toward the end of the first cycle could significantly improve the time for second and subsequent cycles.

Subsequent effort will depend on the potential shown in the pilot operations. The seed research program will be one of support in the early stages of development supplemented with on-going advice should the grower decide to continue developing the program.

The use of the peat cube as a container system for black spruce warrants further work. Without container walls, an air-pruned laterally developed root system is achieved. With no walls, there is no cost of containers. The system is seen as having its greatest potential for planting at the surface on moist sites, or where natural forms of mulch exist at the surface on fresh sites.

(D.A. Skeates)

Coniferous Seed Production

Monitoring Spruce Seed Production

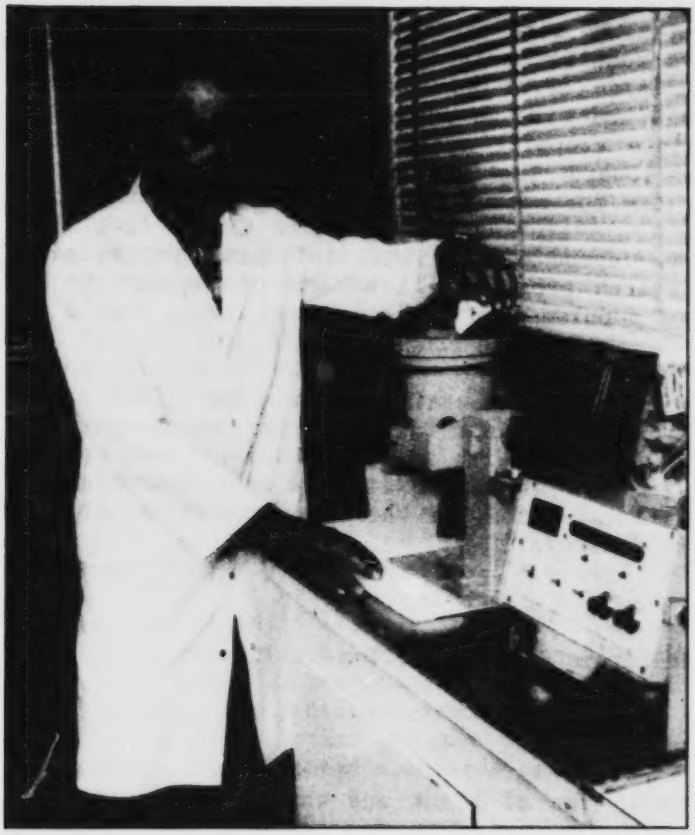
As in past years, production of black and white spruce cones was monitored across Ontario in cooperation with the Great Lakes Forest Centre (GLFC). No significant crops of white spruce were observed anywhere in Ontario. Promising moderate crops of black spruce flowers were wiped out in many areas of northern Ontario and severely damaged in other areas. A real need is seen for published annual cone crop reviews.

Collections were continued in the light to medium crops of black spruce in the Longlac seed orchard of Kimberly Clark and in seed production areas in Nipigon District. Collections from a natural seed production area in Geraldton and plantation seed production areas in Kapuskasing and Cochrane Districts were not possible because of unavailability of appropriate equipment. Collections were made from a limited number of clones in the Matawin black spruce seed orchard for comparison of seed yield and quality with ramets of the same clones in the Kimberly Clark seed orchard.

A journal article was submitted in cooperation with V.F. Haavisto on potential and actual yields of seed. A second was prepared and sent out for review on yields of cones and seed from Ontario collections. Preliminary data was analysed on the relationship of seed yield and seed weight to cone size. These are initial papers in a series on factors influencing yield and quality of black spruce cones and seed.

Discussions were conducted with seed scientists of the federal laboratories in Ontario. Closer collaboration is planned in the fields of Norway spruce and black spruce seed quality and seed orchard management with scientists of the National Tree Seed Centre at Petawawa, Ontario. Similarly, cooperative projects are in place with seed scientists of GLFC on factors influencing seed production.

(D.A. Skeates)



This seed counter is being used by Denzil Irving to monitor black spruce seed production.

White Spruce Seed Source Studies

A Program of White Spruce Trials

Cooperative studies in conjunction with the Tree Genetics Unit of the Petawawa National Forestry Institute (PNFI) were continued in 1986. With the planting of a regional trial near the Swastika Forest Station, the establishment phase of this program has been completed. The project has involved integrated federal-provincial cone-collection crews, close cooperation in growing experimental stock, and shared responsibilities for planting and measurement. The program involves regional provenance trials (OTIFBI); all-range provenance trials, ie. regional plus all-range component (OTIFBI/PNFI); and progeny trials (PNFI). Seventeen experimental plantations have been planted, usually with 80 sources per experiment. Close to 200 sources were collected in Ontario, about 10 trees collected per source.

Nursery heights were assessed for each experiment before outplanting. Initial heights in the field were also measured for each experiment. Collections have been computerized with the intent of publishing collection records. Similarly, layout records have been compiled for a second publication.

Experiments to date are summarized in Table 1, opposite.

TABLE 1 Experimental plantations by site region and location

	Site Region	All Range	Regional	Progeny	Locations
A 1-4	3S-5S	1	3		Dryden, Fort Frances, Kenora, Red Lake
B 1-3	3W-4W	1	2		Nipigon, Shibandovan Man.
C 1-2	5E			2	North Bay and PNFI
D 1-3	4E-5E	1	2		Sudbury, Chapleau, Minden
E 1-2	3E	1	1		Hearst, Kirkland Lk.
F 1-2	6E	1	1		Cornwall, Owen Sound
G 1	All site regions	1			PNFI

Nursery data is being compiled and analysed for a preliminary assessment of provenance performance. Heights five mean years from establishment were measured in the Cornwall and Owen Sound experiments. Measurements are being maintained on a five-year basis for all experiments, and maintenance work is being conducted whenever required.

On the basis of early results, stand tests have been prepared for Nipigon, Geraldton and Manitouwadge. Comprising the 10 sources with the greatest potential for each district, tests were planted by the district.

(D.A. Skeates)

STOCK PRODUCTION

Cellular Physiology

Dormancy and Frost Hardiness

Determination of dormancy in nursery stock is important because the best time for overwinter storage or for outplanting is when the stock is fully dormant. This increases survival and subsequent growth after outplanting. Two approaches for dormancy determination are being tested: i) physical and ii) chemical.

Physical Techniques:

Electrical impedance has been selected as the most reliable physical method of determining dormancy of bare-root nursery stock. The results so far indicate that the transition from unsafe lifting to safe lifting is abrupt but measurable. There are indications that very late fall lifting is detrimental. Electrical impedance safe-lifting zones for overwinter frozen storage are being established in 1986 and 1987 at most Ontario nurseries.

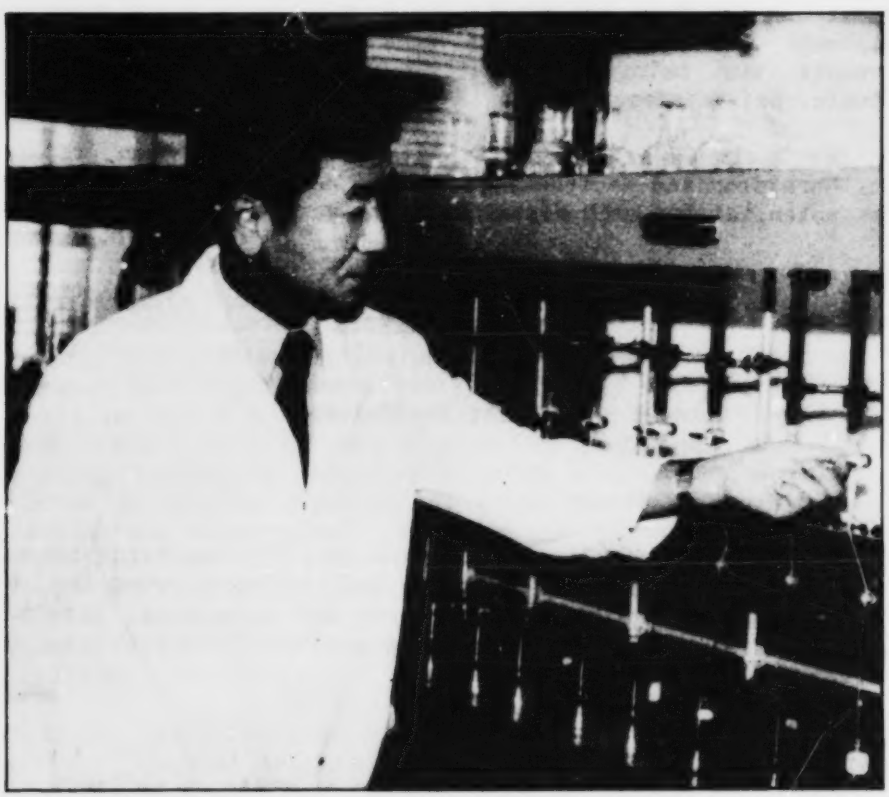
Overwinter frozen storage of bare-root shipping stock plays an important role in the reforestation strategy of Ontario. We believe that major improvements in the reliability of overwinter frozen storage will be forthcoming with the implementation of the electrical impedance method for determining when stock is ready for lifting in the fall. Early investigative work at Midhurst and Swastika nurseries over the past three years and at Gogama, Thunder Bay and Kemptville nurseries for one year demonstrated that red pine, white pine, white spruce, black spruce and jack pine could all be successfully overwintered in frozen storage.

In the fall of 1986, semi-operational trials with the electrical impedance technique were completed at Thunder Bay, Chapleau, Gogama, Swastika, Midhurst, Orono and Kemptville. With the exception of Chapleau and Gogama, where an early freeze-up prohibited the lifting of jack pine, the prospects for full implementation of the electrical impedance technique look promising.

Early results on conditioning planting stock for overwinter frozen storage by root wrenching and/or root pruning or by temperature manipulation indicate that some combinations of cultural practices can also be used to enhance the reliability of overwinter frozen storage.

(G. Racey, C. Glerum and R. Hutchison)

Chemical Techniques:



Young-Tae Kim is demonstrating the automated ion-exchange column system developed at OTIFBI for separation of compounds, concentrating and purifying samples, and gel filtration.

The chemical technique involves monitoring the seasonal patterns of amino acids within the seedlings. Standardized extraction procedures are now used to extract amino acids from freeze-dried needles and root tissue. So far 20 amino acids have been identified: alanine, arginine, asparagine, aspartic acid, glutamic acid, glutamine, glycine, histidine, isoleucine, leucine, lysine, methionine, phenylalanine, proline, serine, threonine, tryptophane, tyrosine, valine and γ-amino-n-butylic acid.

The amino acid patterns for all conifer species tested (red, white and jack pine, and white and black spruce) appear to be similar except for variations in concentrations. The method to determine amino acid concentrations developed in 1983 used thin-layer chromatographs and was replaced in early 1986 by a high-performance liquid chromatograph. The amino acid tryptophane exhibits a distinct and significant seasonal trend, and appears to be the most promising amino acid for our purposes (i.e., indicator compound).

(Y.T. Kim and C. Glerum)

Detection of Seedling Damage

The detection of seedling damage is invaluable for predicting future performance or vitality. Whereas morphological damage is easily detected and evaluated, physiological damage is more difficult to discern, particularly in the short run. Varying degrees of disruption to cellular membranes leads to subsequent leakage of solutes into the relatively pure xylem sap. Since foliar damage on exposure to freezing temperatures declines as seedlings undergo physiological change during dormancy and frost hardiness development, it was hypothesized that there would be a concurrent decline in the leakage of solutes into the xylem stream and a decrease (becomes more negative) in the osmotic potential of the xylem sap.

Test procedures were carried out on seedlings from two private production centres during the fall of 1986 to evaluate foliar damage as a result of being subjected to freezing temperatures as they progressed through dormancy and frost hardiness development. Results suggested that seedlings from one nursery suffered cellular damage, as indicated in a rapid decline in osmotic potential, at the time seedlings were exposed to freezing temperatures during movement from the greenhouse to an outside storage area. It is believed that cellular damage occurred because of insufficient development of cold hardiness. An early spring analysis of growth of seedlings from the same seedlot confirmed the presence of damage.

We will continue to investigate the usefulness of detecting seedling damage by measuring changes in osmotic potential of xylem sap extracted from seedlings subjected to artificial freezing temperatures during frost hardiness development.

(K.M. McClain)

Whole-Tree Physiology: Nursery Stock Stress Resistance

Plantation failures, when they occur, can often be attributed to the inability of planted tree seedlings to withstand one of a number of stresses, including drought, heat and frost. Our work continues to focus on developing procedures to evaluate seedling stress resistance and to

find cultural methods whereby stress resistance can be increased, as described below.

Measuring the Wilting Point of Tree Seedlings

The wilting point is critical to tree seedlings because it marks the point at which growth can no longer proceed due to the loss of cell turgor. For this reason, the wilting point is a logical criterion to use to determine a critical level of seedling drought. Using the pressure chamber, a portable field and laboratory instrument, it is possible to measure the plant moisture stress at which wilting occurs (a "physiological" wilting point occurs in woody stems, even though visual signs of wilting are not evident). We have developed a practical "pressure-volume" procedure by which wilting can be assessed at tree nurseries prior to shipping stock to the field for planting. Field staff can then measure the plant moisture stress of tree seedlings at the planting site and can take remedial action if the level of stress of the stock is near the wilting point.

(S.J. Colombo)

Root Hydraulic Conductivity

Seedlings which have a large capacity to absorb water following planting will be less prone to suffer from drought. The capacity of seedlings to absorb water, or root hydraulic conductivity, is therefore being investigated. We can measure root hydraulic conductivity using the pressure chamber by placing a seedling root system (shoot removed) in water inside the chamber, with the cut stem protruding out of the chamber. Increasing the chamber pressure causes water to move through the root system, mimicking the suction force created by the loss of water from the shoot by transpiration. By measuring root hydraulic conductivity at a range of pressures, we can define the pressure—water flux relationship that determines the ability of seedlings to absorb water under increasing moisture stress.

In our initial work we have described the nature of the pressure—water flux relationship for one-year-old black spruce container seedlings as they resume growth following overwintering. The pressure—water flux relationship consisted of three distinct regions: i) an initial region at which water flows slowly and increases only slightly with increasing pressure; ii) a threshold pressure beyond which hydraulic conductivity increases linearly with further increases in pressure; and iii) an upper threshold pressure beyond which flow rates do not increase. We have found that hydraulic conductivity increases by up to five times in the first 30 days following overwintering, and that these increases roughly correspond to increases in new white root production by the seedlings. Our goal is to identify nursery cultural practices which produce seedlings with favourable pressure—water flux patterns. By so doing we could increase a seedling's ability to absorb water, thereby improving growth and reducing the risk of seedling mortality or damage due to drought after planting.

(S.J. Colombo)

Development of Resistance to Winter-Drying in Spruce Container Stock

Desiccation has caused extensive losses of overwintered spruce container stock. This most often occurs during periods of thaw in the winter or early spring when the shoots are exposed but the roots remain

frozen. Evidence from field tests suggests that seedlings which have been hardened using warm temperatures during Extended Greenhouse Culture have a greater resistance to desiccation than seedlings hardened under cool temperatures. In order to determine the cultural conditions which result in the development of maximum desiccation resistance, a new project was initiated in 1986.

Our hypothesis is that spruce seedlings are susceptible to winter desiccation due to incomplete maturation of needle tissues as a result of cold temperatures during needle development. The minimum period of warm-temperature hardening required for full needle maturation could, therefore, be an important consideration for hardening container stock. To explore this hypothesis, needles from first-year black spruce container seedlings were collected and examined during development under warm or cool hardening conditions to follow the development of the cuticle and mesophyll cell layers. At the same time, the desiccation resistance of seedling shoots hardened under warm or cool conditions was measured to determine whether a direct relationship could be found with needle maturation.

(S.J. Colombo)

Preconditioning Nursery Stock for Drought and Heat Tolerance

Treatments are being developed and tested for their ability to increase the tolerance of container seedlings to post-planting stresses (ie. drought and high temperatures) encountered on harsh planting sites.

Drought Conditioning:

Osmotic adjustment, a mechanism which facilitates turgor maintenance through the active accumulation of solutes in plant cells, thereby prolonging survival and growth under water stress, has been demonstrated in roots and shoots of drought-conditioned spruce and jack pine seedlings. In growth-room trials, seedlings were drought-conditioned by withholding water for four days (moderately stressed) and seven days (highly stressed). Stress levels were monitored by measuring seedling pre-dawn water potential. The response of shoot and root water potential components was determined using a vapour pressure osmometer in conjunction with pressure-volume analysis. In water-stressed and unstressed seedlings of white spruce and jack pine, roots displayed a larger relative decrease in osmotic potential than shoots, indicating that the roots are a primary site for osmotic adjustment. The effect of moderate water stress on osmotic adjustment was generally intermediate between the unstressed and high-stress levels. Seedling responses to drought conditioning are being examined under semi-operational greenhouse conditions.

Bud Initiation:

Temperatures on cutover boreal sites can exceed 50°C and have caused extensive seedling mortality in certain years. Actively growing overwintered two-year-old black spruce seedlings were compared with seedlings which had been treated with two weeks of short photoperiod to induce bud initiation. The bud-initiated seedlings showed greater tolerance to high temperatures imposed in an environmental test chamber. At 42°C, actively growing seedlings had damage to almost half of the length of the second-year shoot, while the bud-initiated seedlings were undamaged. Damage was also significantly reduced at 45°C and 50°C in

bud-initiated seedlings compared to actively growing stock. Bud-initiated stock is being evaluated under semi-operational planting conditions at the Midhurst Research Station.

Ion Loading:

"Loading" seedlings with potassium salts via soil drenching is being tested for its ability to suppress seedling transpiration and hence water loss. A reduction in seedling water loss could impart a significant survival advantage under field conditions where water is limited. This antitranspirant effect has been observed in seedlings loaded with potassium malate (concentration of 50-100 mM) under both growth room and field conditions. In the field, diurnal monitoring of transpiration and stomatal resistance (using a steady-state porometer) is being related to several microenvironmental factors (soil ψ, air and soil surface temperatures, relative humidity and photosynthetically active radiation).

(R. Koppenaal & S.J. Colombo)

Computer Techniques in Seedling Water Relations

To simplify the tedious task of constructing pressure-volume (P-V) curves and to reduce the potential for error, the three principal phases of this work—data capture, analysis, and graphical display—have been computerized. This venture is being undertaken with the cooperation of Robert Forslund and Linda Kapron, OTIFBI's Northern Forest Research Unit. Computer analysis programs developed by Dr. Robert Joly, Professor, Purdue University, along with other software developed as part of the project, form the basis for the computerized technique. Although the individual components of the software are complete, they have yet to be integrated.

The first component of the software allows for the input of fresh sample weight, dry sample weight, and balance pressures, and the automatic capture of weight of expressed cell sap for up to three sample shoots run simultaneously. The second component provides the best definition of the linear segment of the P-V curves and calculates point estimates of osmotic potential at zero turgor (OPZT) and at full turgor (OPFT) along with the relative apoplasmic water content (R*a). The non-linear portion of the P-V curve, i.e. in the region of positive turgor, is modelled using an iterative process and is constrained to join the linear function at the critical value of relative water content where turgor potential is estimated to be zero.

In addition to numerical estimates of the water relation parameters described above, the program provides for the plotting of various relationships, e.g. the P-V curve (1/P versus the weight of expressed sap and 1/P versus relative water content), the Hofler diagram, turgor pressure vs. plant water potential, modulus of elasticity vs. relative water content, plant water potential vs. relative symplasmic water loss, and turgor pressure vs. relative symplasmic water content.

This computerized analysis has greatly enhanced construction of P-V curves as well as interpretation of plant water relations. In future work, particular emphasis will be placed upon quantifying specific plant water relation parameters of young conifer seedlings conditioned by nursery cultural practices to improve performance potential on drought-prone sites.

(K.M. McClain)

Container Seedling Production

Hardening Regimes for Overwintering Spruce Container Seedlings

The investigation of factors influencing the development of winter hardiness remained the primary focus of container-stock-related research at OTIFBI in 1986.

In one trial in 1986, the relationship between seedling bud dormancy, root and shoot frost hardiness and the ability to survive overwinter frozen storage was investigated using black spruce container seedlings in Extended Greenhouse Culture. Results showed that bud dormancy (measured as the number of days required for 50% of the seedlings to break bud under long days/warm temperatures) was greatest—requiring 36 days—just after bud initiation, but declined continuously to require only six days eight weeks following bud initiation. Shoot frost hardiness (measured by the diffusate-conductivity method) stayed between -5° and -7.5°C for three weeks following bud initiation, but reached a level of -40°C eight weeks after bud initiation. Root frost hardiness increased following bud initiation and was inversely correlated with the number of white roots present on seedlings. Shoot frost hardiness was the best predictor of seedling survival following frozen storage.

(S.J. Colombo)

Regional Frost Hardiness Testing Laboratories

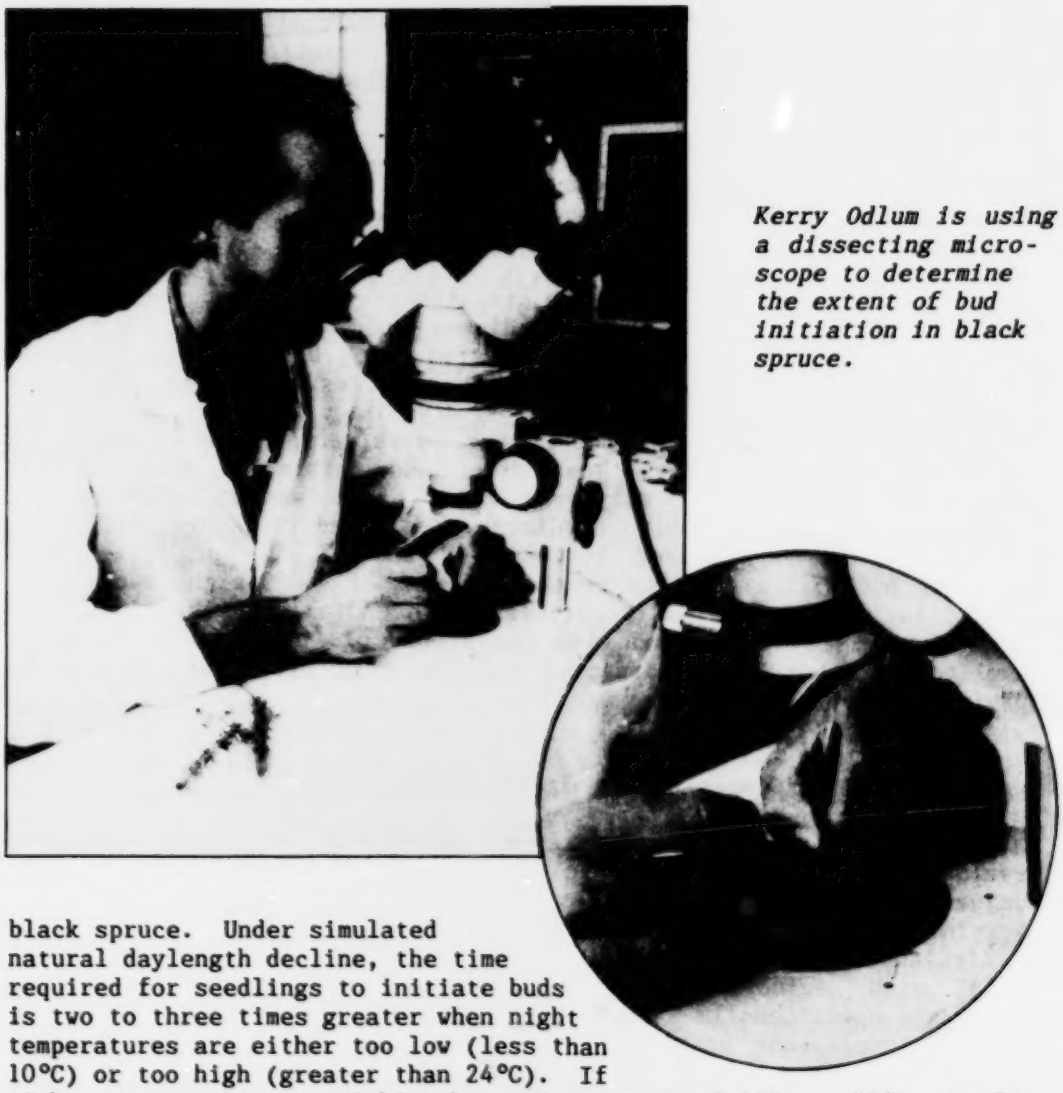
The procedures for operational monitoring of frost hardiness developed at OTIFBI continue to be used in regional laboratories in conjunction with the Extended Greenhouse Culture hardening regime for overwintering container seedlings. Laboratories in Ontario are located in Kirkland Lake and Dryden, with testing for Thunder Bay conducted at OTIFBI with regional support. In 1986 a new test procedure was introduced operationally which reduced test duration from 72 hours to 24 hours. Involvement with regional laboratories and container seedling nurseries is being maintained on a consultative basis.

(S.J. Colombo)

Bud Initiation in Greenhouse Black Spruce Production

Bud initiation in seedlings of black spruce results in the cessation of shoot growth and the commencement of bud development, eventually leading to increased shoot frost hardiness. For growers, knowledge of how the greenhouse environment influences bud initiation is critical when making decisions regarding a crop's growing regime. If cessation of shoot elongation or the development of increased shoot frost hardiness is required, then conditions within the greenhouse should be set for rapid and consistent bud initiation. If continued shoot elongation is required, then greenhouse conditions should be such that bud initiation will not occur. The cultural factors influencing bud initiation are being studied as part of a three-year research program under the auspices of the Canada-Ontario Joint Forest Research Agreement (Project No. 33501).

It has been determined in plant growth chamber studies that night temperatures have a profound effect on the speed of bud initation on



Kerry Odlum is using a dissecting microscope to determine the extent of bud initiation in black spruce.

black spruce. Under simulated natural daylength decline, the time required for seedlings to initiate buds is two to three times greater when night temperatures are either too lov (less than 10°C) or too high (greater than 24°C). If night temperatures are within the optimum range of 14°C to 22°C, complete bud initiation occurs within 15 days of the start of daylength decline. Day temperatures apparently have little or no effect on the speed of bud initiation.

Drought stressing and nutrient leaching are two treatments commonly used in operational bud initation regimes. The effectiveness of these treatments, however, has not been well documented, and both are being studied independently and in conjunction with one another in greenhouse and in plant growth chamber trials.

To assess the effect that operational bud initiation regimes have upon survival and growth of outplanted seedlings, field plantations have been established in the Northern Region and at the Midhurst Research Station of OTIFBI. One plantation consisted of seedlings from short daylength, extended greenhouse culture and summer greenhouse removal bud initiation regimes. Although the second-year shoots of seedlings with buds which were initiated and developed under short daylengths elongated at the same rate as did seedlings from the other regimes, they continued to elongate for a longer period into the late summer. The implications of prolonged growth may be both positive and negative: a longer period of

growth results in greater seedling height, while increasing the risk of non-hardy shoots encountering early fall frosts.

(K.D. Odlum and S.J. Colombo)

Outplanting Performance of Coniferous Planting Stock

Container Stock vs. Bare-Root Stock

In the spring of 1979, jack pine and black spruce seedlings overwintered in Japanese paper pots and Spencer-Lemaire containers were outplanted with bare-root stock in the Wawa district on fresh and on dry sites. The purpose of the planting was to test the container stock and determine to what extent site differences influence survival and subsequent growth. To extend the planting season, three plantings were spread out over a period of one month. Some spring-sown stock was also planted. All stock was cold-stored ($\pm$1°C) between plantings.

First-year results suggest that bare-root stock is better able to withstand cold storage than is container stock. After eight growing seasons in the field, the survival of the overwintered paperpot and Spencer-Lemaire stock was significantly better than the bare-root stock. Height differences, which were significant at time of planting, were no longer significant by the third year on the fresh site, and by the fourth year on the dry site. There were no significant differences in survival between the overwintered paperpot and the spring-sown paperpot. The total height of the spring-sown paperpot seedlings after eight growing seasons was equivalent to the total height of the overwintered paperpot seedlings after six growing seasons.

Multiple leadering in black spruce occurred more frequently on the fresh site than on the dry site because seedlings on the fresh site had been damaged more severely by frost. After eight growing seasons, the black spruce showed differences in volume but not in height between sites. Jack pine, on the other hand, suffered little to no externally visible frost injury on either site. Pines on the fresh site were significantly larger in both height and volume than on the dry site. Frost rings occurred in both species and on both sites, but with greater severity on the fresh site.

(C. Glerum and J. Paterson)

Stock Type Development and Testing

An active program of stock type development continued at several Ontario nurseries, using techniques such as root wrenching, undercutting and transplanting. These techniques have been successful in altering the morphological and physiological attributes of bare-root planting stock.

Selected undercutting and root wrenching treatments can control height and lammas growth on jack pine, increase root volume of red and white pine, improve balance and increase root regeneration capacity. Ongoing research and development will clearly define cultural treatments which will produce new and improved stock types for outplanting.

The stock type testing program continued with a white pine underplanting near South River to determine if current stock types are capable of duplicating the favourable results obtained with the no-longer-produced 2+2 white pine stock type. Continued stock type testing

programs are required to determine whether current production standards are sufficient for the silvicultural uses to which the stock is put.

(G. Racey, C. Glerum and R. Hutchison)

Greenhouse vs. Standard Transplants

Kirkland Lake District

Greenhouse transplants have the potential to reduce the time required to produce an acceptable seedling by up to two years. Normal transplants require seedlings to grow for 1 1/2 years in a seedling bed to reach acceptable size for transplanting. In the uncontrolled environment of a seedling bed, seed germination is often quite variable, and large cull percentages are not uncommon when lifting trees for transplanting. Moving the seedling stage into a controlled greenhouse environment creates a more uniform seed germination and growth rate, reducing the percentage cull and the time required to grow an acceptable tree for transplanting.

To test the field performance of trees grown under different cultural practices, an outplanting was conducted in Flavelle Township of the Kirkland Lake District during the spring of 1985. In this study, three stock types were compared: G+1, G + 1-1/2 and standard 1-1/2 + 1-1/2. Prior to outplanting, root volume, stem diameters and heights were taken. These trees were then outplanted and at the end of one and two years were excavated and reassessed.

Initial tests show the G + 1-1/2 and standard 1-1/2 + 1-1/2 stock types to be establishing and growing at very similar rates. Increases in root volume, stem diameter and height increment are similar between these stock types, and both are significantly better than the G+1 stock.

Kapuskasing District

An outplanting similar to that outlined for Kirkland Lake was established in the spring of 1986 in Teetzel Township. The same stock types were tested using both fresh-lifted stock and overwintered frozen-stored stock. First-year results were collected during the fall of 1986 but as yet have not been analysed. Survival was good on all trees planted, and results are expected to be similar to those in the Kirkland Lake study.

(J. Paterson)

Long-Term Effects of Handling and Planting

Red Pine: Ten-Year Results

Ten-year results from a careful-handling-and-planting study conducted in southern Ontario during 1976 have been collected and analysed. In this study, careful research handling and planting were compared to normal handling and planting procedures employed operationally.

Results show research survivals at 87% vs. 69% and basal areas of 3.42 m^2.ha (research) vs. 2.49 m^2.ha (operational) which equated to a net loss of 21% in survival and 27% in basal area attributable to less careful handling and planting procedures.

Needle length in the first two years after outplanting was used in

this study to indicate the trees' ability to establish. After ten years, those trees having long needles in the first two years have outperformed the trees with short needles. Needle length is a good indicator of establishment; slow establishment, indicated by short needles, is still evident at ten years.

A research report outlining the ten year results is presently being reviewed and should be available by 1988.

(J. Paterson)

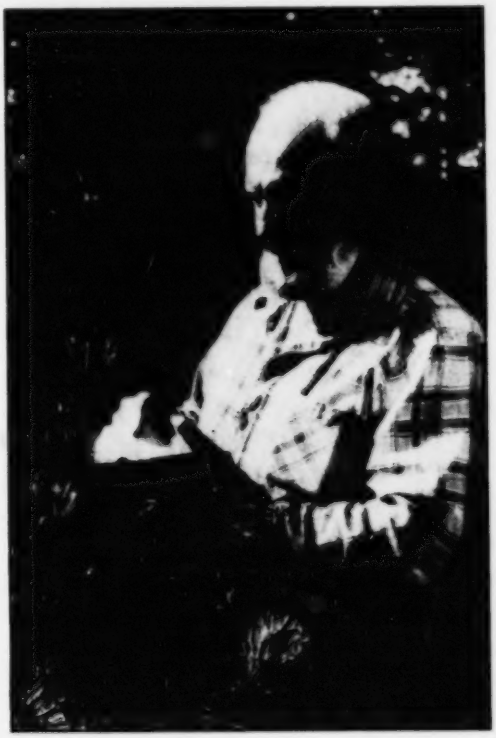
Operational Outplantings of Multiple-Leadered Spruce

Timmins District: White Spruce

During the spring of 1983, some 3 000 2+2 and 450 1+2 bare-root white spruce with varying degrees of multiple-leadering were outplanted on a shear-bladed site in Carscallen Township. Field assessments have been carried out each fall for survival and annual increment, and each tree has been classified according to its degree of multiple-leadering.

By the third year after outplanting (1985), less than 10% of the trees in this study remained multiple-leadered. That year, the trees grew an average of 16 cm. During August 1985 the trees were aerial-sprayed with Roundup for competition release. In June 1986 a severe frost occurred on this site, with devastating effects on the trees now exposed due to competition release. Although survival was unaffected, terminal increment and form were. Increment dropped from 16 cm to 12 cm and multiple-leadering went from less than 10% to over 30% of the total sample. All exposed trees were affected; however, those unexposed showed little damage. Had this site not been released, increment might have reached 20 cm or more, and multiple-leadering might have been further reduced.

Competition release in 1985 coupled with frost in 1986 has obviously affected the growth and form of trees in this study. How long this effect will last can be seen only through continuous monitoring. Trees will be assessed during the fall of 1987 (fifth year), and a research report will be written outlining the results to five years.



John Paterson measures red pine needle length.

Dryden District: Black Spruce

A similar study to that outlined for white spruce was conducted in the spring of 1984 for black spruce. Results after two years were very

similar to those for white spruce. Third-year results were not collected, but fourth-year assessments will be conducted in the fall of 1987. An internal report showing the results to four years will be produced during the winter of 1988.

(J. Paterson)

Jack Pine Needle Classification

As a cooperative study with the Northern Forest Development Group (NFDG) in Timmins, needle lengths of jack pine are being assessed to see if similar predictive qualities to those found in red pine exist. The needle work is part of a planting demonstration area established in 1986 in Garibaldi Township of the Gogama District.

The first-year results show a relationship between the length of the needles formed in the last year of nursery growth to height increment in the first year after outplanting. Needles formed on the first-year increment also show a good relationship to the treatments applied. Planting effects are being expressed in the length of needles formed on the terminal shoot.

An internal report outlining the first-year results of this study is with NFDG.

(J. Paterson)

Seedling Stock Evaluation

Losses in overwintered container stock can have a significant impact on the supply of healthy, vigorous seedlings for reforestation purposes. Conclusions drawn from studies of stock losses have yet to identify a single causal factor responsible for seedling mortality. Instead, many factors have been implicated, each acting at some point from the time of final culture to promote dormancy and frost hardiness development, to the time of shipment in the spring. The influence of each factor is compounded to predispose seedlings to spring mortality under stressful conditions at time of snow melt. It is important therefore to initiate and develop test procedures to evaluate seedling response potential and help predict field performance.

Tests were begun in January 1986 on black spruce container seedlings obtained from the five private growers in the vicinity of Thunder Bay. Apart from morphological assessments, evaluations were conducted to determine the rate of bud burst, root growth potential, and possible internal foliar damage (from freezing). Based upon the above parameters, as well as shoot and stem caliper increments, field performance of the same stock lots was projected. Apart from one discrepancy, performance (survival) rankings among nurseries coincided with projections. During the conduct of procedures to determine possible internal damage to foliage by pressure-volume analysis, it was encouraging to observe that those seedlings with marked disruption to the form of the typical P-V curve failed to exhibit a growth response similar to that of a healthy seedling. The diagnostic possibilities of the pressure-volume curve to evaluate seedling vitality will be explored further. Other physiological testing will be conducted along similar lines with emphasis on optimum timing of test procedures, the conditions under which they are performed, and subsequent field performance.

(K.M. McClain)

Performance of Seedlings from Private Production Facilities

Because of variable field performance of containerized seedling stock from private production facilities in the vicinity of Thunder Bay, seedling size/performance relationships were reviewed for each production centre across sites of varying competitiveness. A cooperative study was initiated with Abitibi-Price Inc., Thunder Bay, in which container seedlings from four production centres were planted on a low-competition site with a dry moisture regime. Analysis showed that relationships between initial morphological features and field performance were weak, and varied substantially from one production centre to another. Survival evaluations made three weeks after planting and again in the fall indicated that seedling lots possessed unique performance potentials on the dry moisture regime site. Survival of the same seedling lots from the same nurseries on a site with a moist moisture regime was, in all cases, greater than 96%.

This preliminary study indicates that clients (FMA holders) should not expect similar performance from seedling stock obtained from different growers. Seedling lots of low quality may attain an acceptably high level of survival on favorable sites, but only minimal growth. Similar work will continue, but attention will be focused upon the physiological and morphological attributes that can be altered through nursery cultural practices. The extent to which site factors limit the extent of their effectiveness will be also considered.

(K.M. McClain)

Nursery Water Management Techniques

Soil Water Transport Models for Improved Solute Management in Nurseries

The sandy soils typically selected for nursery sites throughout North America have one major drawback: a soil matrix characterized by low water retention and high drainage. The practice of periodic root undercutting adopted by Ontario nurserymen has limited the effective root zone to only 25-27 cm. Any available moisture beyond this limit cannot be extracted by roots in response to the atmospheric demand for evapotranspiration.

Two distinct types of infiltration of water into sandy soils occur in nature. Sheet infiltration occurs during a heavy rainfall of sufficient intensity to form excess liquid water on the surface of the sand. Depending on soil texture, this condition is maintained only for a short interval, but gives the soil an intense flush. The second type of infiltration occurs when the rate of rainfall or irrigation is less than the infiltration capacity of the sand. The unsaturated flow percolates through the soil matrix with limited lateral diffusion, subject mostly to gravitation. Water moves through a porous medium according to Darcy's law, formulated mathematically as a function of moisture and hydraulic conductivity. Since hydraulic conductivity is a function of moisture concentration and relates to the whole soil profile over time, Darcy's law must be written in differential form and solved with complicated numerical integration procedures.

Other factors involved in the soil-water balance of a nursery crop are: physical definition of the crop (height, roughness, cover); evapotranspirational demand; and the root extraction of water. A conceptual model of transport processes occuring during a typical growing-season day with precipitation input depicts soil losing solute from its unsaturated zone towards the ground water at a rate proportional to its water content. When the rain starts, the soil moisture concentration increases, and the next front advances deeper. The reverse vertical flow is controlled by the evapotranspirational demand generated by the atmosphere. This demand is split, depending on the percentage of the area covered by a crop, into a surface evaporation component that draws water from the shallow upper layer of soil, and a transpiration component which transmits this demand to the root system.

The root system is defined in terms of shape (volume explored at various depths) and effectiveness. The demand for transpiration is satisfied between suction head boundaries limited by the water-related soil characteristics (wilting point and full saturation). Inputs to the model include: rain and irrigation for calculating water balance, and the meteorological parameters for evapotranspiration, including global and net radiation, wind, cloudiness (capacity and amount), relative humidity, dew-point, and dry-bulb and wet-bulb temperatures.

Subject to local soil characteristics and meteorological inputs, the model is set up as a system of differential equations and solved through numerical procedures every hour. The model is calibrated locally by inputting measured hydraulic conductivity and a crop definition as close as possible to reality. During the growing season, the crop definition is adjusted daily to reflect increased root exploration and leaf area.

Each hour, the model solves the system of differential equations by integrating between physical boundaries. The surface particular to a certain condition at soil surface or to the bottom of root zone, including appearance of ground water in profile, can be specified.

The outputs of the model are numerous, both graphic and tabular. In graphic form one can obtain the soil suction head, soil hydraulic conductivity and soil water diffusivity as functions of soil moisture concentration for any soil horizon. Also, diagrams of suction head, soil moisture, plant-available water, surface evaporation, actual transpiration, potential evapotranspiration and soil water percolation as a function of time can be obtained. In tabular form information is provided with respect to soil moisture profile, surface evaporation, actual transpiration, infiltration and flux of water through bottom of root zone, every hour or at other chosen intervals, plus daily summaries of the above.

The model has been elaborated (COFRDA Project 33505) as a research tool oriented towards integration with current water and nutrient management practices. It is compatible with the current formats and software that process the climatic information collected by the automatic weather stations installed at five nurseries. The model allows for detailed studies of water and nutrient balance, and can be run for various time intervals from one day up to the whole growing season. As a future development, the model will be expanded to encompass a nitrogen extraction subroutine. Together with the water balance, this is expected to yield information about the amount of fertilizer leached subject to natural rain or excessive irrigation.

Although its current form has been configured for nursery crops and irrigation/fertilization activities, the expansion of the same approach to a different crop is possible. For example, a realistic history of the water balance of forest stands could be reconstructed from meteorological records and local measurements of soil hydraulic conductivity. It would then become possible to assess a growing season in terms of soil moisture availability through a distribution of days over various stress intensities, which could subsequently be related to the current year's volume increment obtained with the TRIM system.

Other applications of the expanded model include comparison between stands with different compositions and optimized operation of effluent disposal areas combined with intensive silviculture.

(C.S. Papadopol)

Evapotranspirational Demand of Nursery Crops

There is an urgent need for sound information on nursery crop water consumption and its relation to the amount of irrigation water required for satisfactory growth. This information must be integrated with the fertilization schedule and rain probabilities: because of the shallow root-zone of nursery crops and the permeable nature of nursery soils, heavy rain or excessive irrigation may carry fertilizers out of reach of the roots more often than is normally believed. Precise calculation of water consumption based on climate and crop may help avoid insufficient or excessive irrigation dosages.

Numerous formulae and methods have been proposed over the years for calculating the atmospheric demand for evapotranspiration, all of which use climatic information in their development. Most of the empirical methods require the input of only one or two commonly available parameters such as air temperature or air temperature plus radiation. While the empirical methods are convenient, particularly since these data are normally available, their success depends on the correlation of potential evapotranspiration with input variables. Empirical methods may, however, not operate satisfactorily outside the range where the original correlations were developed.

The combination method for estimating potential evapotranspiration is based on the physics of the evaporation process. This method involves the simultaneous solution of the aerodynamic equation and the energy balance equation, and can work with climatic measurements performed at only one level in the atmosphere. Input requirements are more stringent than in most empirical methods, and use air temperature, humidity, solar radiation (global or net) and wind parameters. In the last four decades since the original Penman equation was released, the combination concept has evolved into numerous forms currently in use mainly in irrigated agriculture in the United States. Among its other advantages, this concept offers potential for working with different time intervals such as a month (for planning purposes), a day (for operational use), or an hour or a fraction of it (for research). Recently, two standards, "grass" and "alfalfa", were defined in order to include a crop element and to allow uniform comparisons between years and localities. But no matter how intricate the calculations required by a certain model, its validity can be established only through actually measuring evapotranspiration, which requires a costly and complicated lysimeter installation.

To evaluate nurseries' seasonal irrigation needs, a large weather data base was established for a number of localities surrounding the point of interest. Data relevant to this application were transferred electronically from Atmospheric Environment Service to OTIFBI (COFRDA Project 33505).

A number of models based on both the empirical and the combination approach have been included in a comprehensive piece of software (programmed in BASIC) to estimate the climatic demand for evaporation and to assess rain probabilities. Since no lysimeter installations with nursery crops are known to exist in Ontario, the results of the models, when run with data for Toronto, are compared with evapotranspiration measured with the Woodbridge lysimeter. (Cooperation of R. Street with respect to access to AES information on evaporation measured with the Woodbridge lysimeter is gratefully acknowledged.)

The analysis now in progress will provide information with respect to: i) accuracy of estimate with empirical models for daily intervals; ii) appropriate wind function for the combination method; and iii) possibility of using a simplified continuous method (Priestley-Taylor) to estimate potential evapotranspiration. Also, for the combination methods, sensitivity analysis performed for each entry variable will show the evaporation change per unit change in any of the input variables.

Further development of this study would include quantification of leaf area influences on actual evapotranspiration, and elaboration of a numerical model for actual evapotranspiration.

(C.S. Papadopol)

Frank Mestyan in the OTIFBI nursery at Maple.

Expansion of Weather Data Collection Systems at Nurseries

Nursery activities are intimately related to weather because operational decisions require a precise timing and dosage in which weather evaluation is a decision factor. In general, an advanced weather station should be considered a necessary facility of the modern nursery. Recent advances in technology have made weather data loggers, sensors and communication devices affordable and highly effective.

The first automatic weather stations were installed at Chapleau (1984) and Thunder Bay (1985), coupled with DEC-350 computers. While the stations were acquired mainly for irrigation rate calculation, which is only a summertime activity, their involvement in nursery management can be more extensive. Since 1986, three other nurseries—St. Williams, Midhurst and Kemptville—have received similar equipment, along with matching software to perform data communications, calculate evapotranspiration demand hourly, and print daily data summaries.

One objective in building this weather data collection network was to secure uniform sampling. The stations therefore have a minimal and identical configuration of sensors linked to the open channels of the micrologger; each nursery may add additional sensors for other elements. In future it will be possible to preserve comparative and historical climatologic information for each nursery.

Some difficulties were experienced in the first years with both hardware (data communication) and training of operators of these systems. OTIFBI has provided the necessary assistance, including local program configuration for Apple III, DEC-350 or IBM-AT. The data archives are now created hourly at each nursery and record the following data: day of year, hour, air temperature (dry bulb), relative humidity, global shortwave radiation, hourly wind run and precipitation. These values together with calculated elements such as evapotranspiration can be displayed as graphs or printed (see Table 2, next page).

Standardization of these records allows the building of a common archive as well as comparison between nurseries. The records also document the development of weather conditions very adequately for studies of growth dynamics, water stress, disease evolution, etc. To date, maintenance of existing records is the responsibility of nurseries. The configuration of data that is collected now will most likely be compatible with the standard being elaborated by the Climate and Meteorology Committee of the American Society of Agricultural Engineers for calculating potential or reference evapotranspiration.

At this stage in the network's evolution, changes in hardware (replacement of DEC-350 with IBM-AT) and in software (coupling of evapotranspiration model with a soil transport model) are taking place, and a comprehensive set of graphics is being developed that will allow the nursery manager to assess the weather situation, including evapotranspirational demand and leaching. The new software will include local rain probabilities as well as information about soil hydraulic conductivity (COFRDA Project 33505). Local rain probabilities and durations of dry/wet clusters of days were developed for each nursery locality by applying statistical methods to records. Integration of this information into the model will increase the effectiveness of irrigation activity and reduce considerably the amount of nutrient leaching.

(C.S. Papadopol)

TABLE 2

Atmospheric Parameters for Day 176

25 June 1986

H	Td oC	Tw oC	Hum %	ESh mb	ERh mb	Rad lg/h	Wind km/h	ET1 cal	ET2 cal	ETc cal	ETp mm
1	6.9	0.0	88.40	9.94	8.78	0.06	4.01	0.0	0.7	0.7	0.0124
2	7.8	0.0	86.70	10.58	9.17	0.06	6.09	0.0	1.0	1.1	0.0183
3	8.3	0.0	85.10	10.95	9.32	0.06	6.22	0.0	1.2	1.2	0.0210
4	7.6	0.0	85.80	10.47	8.98	0.06	6.06	0.0	1.1	1.1	0.0193
5	7.1	0.0	86.70	10.07	8.73	0.17	5.49	0.1	1.0	1.0	0.0177
6	8.6	0.0	82.50	11.19	9.23	3.48	5.56	1.9	1.3	3.2	0.0546
7	11.1	0.0	75.60	13.25	10.02	9.43	7.28	5.4	2.4	7.8	0.1330
8	12.9	0.0	71.00	14.86	10.55	16.16	9.28	9.7	3.6	13.3	0.2252
9	14.6	0.0	64.10	16.58	10.63	22.57	8.16	14.0	4.3	18.3	0.3114
10	15.6	0.0	60.18	17.74	10.68	28.11	9.72	17.9	5.5	23.4	0.3979
11	16.8	0.0	53.55	19.13	10.24	32.27	9.70	21.0	6.6	27.6	0.4707
12	17.3	0.0	46.80	19.73	9.23	33.03	11.73	21.7	8.8	30.5	0.5201
13	17.7	0.0	44.70	20.23	9.04	34.18	11.96	22.6	9.4	32.0	0.5459
14	18.5	0.0	43.23	21.23	9.18	34.04	11.26	22.8	9.4	32.2	0.5504
15	18.8	0.0	43.06	21.69	9.34	31.04	11.24	20.9	9.5	30.5	0.5202
16	19.0	0.0	42.68	21.92	9.36	26.29	10.35	17.8	9.1	26.9	0.4587
17	18.5	0.0	43.42	21.30	9.25	19.76	10.35	13.3	8.8	22.1	0.3773
18	17.6	0.0	45.35	20.18	9.15	13.35	8.99	8.8	7.6	16.4	0.2795
19	16.2	0.0	47.31	18.47	8.74	6.60	8.99	4.2	7.0	11.3	0.1918
20	14.4	0.0	52.02	16.38	8.52	0.73	4.33	0.5	3.9	4.4	0.0742
21	12.0	0.0	65.60	14.04	9.21	0.03	2.88	0.0	2.2	2.2	0.0369
22	11.0	0.0	72.30	13.14	9.50	0.05	3.00	0.0	1.7	1.7	0.0295
23	10.9	0.0	72.20	13.05	9.42	0.05	2.62	0.0	1.6	1.6	0.0279
24	10.9	0.0	74.20	13.01	9.65	0.06	3.07	0.0	1.6	1.6	0.0277

Legend : Td - Dry Bulb Temperature, oC
Hum - Air Relative Humidity, %
ESh - Saturated Water Vapor Pressure, mb
ESh - Actual Water Vapor Pressure, mb
Rad - Net Solar Radiation, langley
ET1 - Potential Evapotranspiration due to Heat, cal
ET2 - Potential Evapotranspiration due to Wind, cal
ETc - Total ET for one Hour, cal,
ETp - Potential Evapotranspiration, mm

Summary for DAY 176

-mean AIR TEMPERATURE = 13.33 oC
-mean AIR HUMIDITY = 63.85 %
-tot. RADIATION = 311.64 Lg/day
-tot. D. W. R. = 178.34 km/day

Total Daily EvapoTranspiration :

-due to HEAT 3.460 mm/d or 65.01 %
-due to WIND 1.862 mm/d or 34.99 %

Daily EvTr Potential = 5.322 mm/day

Rejuvenating Older and Damaged Stands

Yellow Birch/Sugar Maple Regeneration and Recruitment

Performance Modelling:

A historical model was developed for the regeneration established in a 1960 partial cutting experiment at Swan Lake for plots affected by site preparation (ie. prescribed fire and/or scarification). Dominant height was regressed over time (up to 211 months) using residual basal area as a co-variate (basal area was dynamic, ie. adjusted to reflect current stocking at each time period). The model expressed significant interaction of time and basal area and explained 88% of variation with Sy.x = 0.70 (metric units). Data suggests that the multiple linear model suffices for a period of 18 years only, after which mortality and senescence of suppressed trees have a pronounced effect on the model's ability to predict. Historical yellow birch census data has been fitted to several non-linear time functions with the objective of predicting survival over time using only original seedbed type and residual overwood basal area values as predictor variables. Future modifications will include non-linear terms and a stochastic element to accommodate the probability of survival. Eventually, this model will have application in simulating management strategies and developing optimal silvicultural prescriptions.

Bill Beekers, Jim Rice and Phocus Ntayombya are measuring the growth and quality of regenerated yellow birch in a research plot at the Swan Lake Research Reserve.

Back-projection of residual stand basal area to precut status was accomplished, indicating that an average of 5.5 $m^2.ha^{-1}$ of overwood basal area was felled in 1960. The basal area removed in this partial cutting varied from 0 to 18 $m^2.ha^{-1}$, or approximately 0% to 70% of the local original basal area. As a result of the "group selection" nature of the cut and the maintenance of "control" or relatively undisturbed portions of the stand, residual growth in the period 1960-1980 averaged approximately 6.5 $m^2.ha^{-1}$, or only about 50% of that expected if the stand had been treated overall using uniform single-tree selection.

A survey of the stem quality of established yellow birch saplings and poles was carried out by means of two continuous transects across zones of low residual basal area associated with group selection. Composite tree quality scores derived from ratings of tree size, bole form, crown size and position were used to associate tree quality with original group basal area distribution (ascertained through back-projection). The objective is to determine optimum group size which will produce satisfactory stocking of crop-tree quality yellow birch.

Interspecific Relationships:

Investigation continued concerning the failure of sugar maple to regenerate successfully in the areas restocked to yellow birch. Inventory of permanently marked census populations of sugar maple seedlings originating from the 1980 seed year indicate average survival of 10.2% (range 0% to 28%) after 60 months. A preliminary study of the possible inhibitory effects of birch litter on maple germination and seedling growth was initiated in 1986.

(H.W. Anderson)

Red Oak Regeneration

Red oak is one of the major species in the northern mixedwood and hardwood cover types of Ontario. However, the relatively large supplies of high-quality timber have disappeared due to overcutting during the last century. Ontario now imports veneer logs of red oak from the USA, along with other heavy hardwoods. Good growth, high quality and high market value make red oak a very desirable species for a great variety of products. Some industries depend on good-quality oak, and demand for sawlogs and veneer in southern Ontario is expected to double by the year 2025. The demand justifies promotion of the regeneration and growing of red oak in southern Ontario.

Natural Regeneration:

Hardwood stands in the Leslie Frost Centre and Parry Sound District were identified and marked for selective cutting to encourage the regeneration of oak. Acorns from these sources will be used also for direct sowing and nursery stock production. Kraft tubes for sowing acorns are being developed for subsequent planting in shelterwood stands, strip-cut stands and red pine plantation openings. Experimental plots were established for planting trials in 1987 in the Bracebridge, Parry Sound and Huronia Forest Districts.

Prescribed Burn in Hardwoods:

A prescribed burn at the Leslie Frost Centre was carried out in October to evaluate its effect on the development of stump sprouts from stunted advanced oak reproduction severely browsed by deer. The

objective is to find out if prolific stump-sprouting will allow a sufficient number of oak to reach the free-to-grow stage, about 2 m in height, in a deeryard area. Another burn is planned for spring of 1987.

Planting of Nursery Stock:

Planting of 1+0 and 1+2 red oak stock continued in the Bracebridge and Whitney Districts in strip-cut stands and forest clearings, respectively. The objective is to establish oak where natural regeneration has failed, or where an admixture of oak to white pine is ecologically and economically desirable.

Plantation Assessments:

Growth data from two red oak plantations established in 1976 and 1977 were summarized for written reports.

(G. Stroempl)

Use of Black Alder for Site Conditioning, Dual-Crop Systems and Reforestation

The approach to growing hardwoods in mixtures is based on the principles of species association and succession. Generally, the technique consists of the initial establishment of a suitable pioneer species for site preconditioning, followed by introduction of sub-climax or climax hardwoods in compatible mixtures.

Such quasi-natural stand development is particularly effective on impoverished, non-forested fields which greatly benefit from the accrual of humus and nutrients, returned annually by the fast-growing pioneer species in their litter and through nitrification (alder, black locust).

Establishment of balanced associations is strongly favoured by the differential requirements and habits of intolerant, semi-tolerant and tolerant species, leading to appreciably improved site utilization and valuable allelopathic relationships. Mixed forest communities exert a profound influence on stand sanitation, preventing wholesale epidemics or complete "wipe-outs" by insects and diseases. They contribute to a richer, more varied ecology, provide a variety of industrial products, and at the same time offer highly pleasing aesthetic and recreational opportunities.

For the above-mentioned reasons, such species as European (black) alder are potentially suitable candidates for rapid improvement and propagation for use as planting stock in highly productive dual-crop forest systems. As a rule, the candidate species mature exceptionally early and are capable of maintaining above-average genetic stability.

In 1986, plantings of black alder progeny from select Central-European sources were established at the Bullen property (Ganaraska), Proctor Tract (Vespra II), Orono and the King Campus of the Seneca College. At the latter site, a biomass-oriented venture directed at biological processing and utilization of wastewater, six additional hybrid poplar sources were set out on about 2.5 ha of effluent-sprayed area. At present, the Seneca plantation comprises over 25 DN clones, two quality willow cultivars and a number of black alder sources. Selections scheduled for planting in 1987 will add up to over 20 ha of forested area.

Serious consideration should be given to black alder for reforestation of sites similar to those of silver maple. The species is a fast grower and can be raised together in symbiotic mixtures with soft maple, cottonwood and ash. It can tolerate a wide range of site conditions and pH ranging from pH 3.5 to pH 8. After harvest it can be reproduced by coppicing, or reforested with seedling stock requiring minimum site preparation. Early production of seed along with cloning should prove invaluable in further genetic improvement. In mixed plantations, black alder can contribute to exceptionally high yields; however, for a successful nurse crop, the spacing should be adjusted to allow for the high crown density and dark-green foliage.

The colour and figure of cured alder wood are most attractive, of an excellent form and colour not unlike gumwood, now in such high demand. The trees lend themselves to the manufacture of solid wood furniture, veneer paneling and other products with lucretive returns. Propagation of quality phenotypes is facilitated mainly by prolific coppicing, but also by layering and by greenwood cuttings.

Eighty black locust progeny were set out for testing, identification of genetic variability and selection of desirable variants under distinct physiographic conditions (such as at Ganaraska and Vespra). The highly heterogeneous species shows appreciable genetic differences in growth potential, stem form, branching habit and phenological development. Such important wood properties as hardiness, durability and resistance to diseases and insects add exceptional value to the properly managed species.

Due to its durability and wood chemistry (flavonoids, etc.), considerable gain can be attained within a relatively short time-span from black locust crops managed intensively for fence posts, shipbuilding, nectar production etc.

Intensive cultivation is a prerequisite for the elimination of black locust borer, for improving wood quality and for shortening rotation. Reproduction by root cuttings, greenwood cuttings and layering helps maintain and enlarge quantities of the most desirable strains.

Additional work was accomplished in establishing dual-crop systems such as white ash, white pine and spruce under black locust nurse crops. To maintain the latter free of locust borer, intensive cultivation to control goldenrod, the insect's secondary host, is of absolute importance.

(P. Jaciw)

Effect of Cutting Method on Natural Aspen and Artificial Spruce Regeneration

In cooperation with the Kirkland Lake District, five clearcut treatments were applied to blocks of varying size and orientation in 1984. The primary objectives were: i) to determine the effect of clearcut size and orientation on aspen regeneration growth and biomass production; ii) to determine the effect of cutting method on the growth of planted white and black spruce; and iii) to evaluate the effect of early release on the growth and development of aspen and planted spruce in a mixedwood stand.

Following three growing seasons, the survival of the planted spruce remains in the 90% range for most of the treatments. A high level of

mortality was observed in the smallest clearcut oriented in the north-south direction. Most of the plots in this treatment were destroyed when the border trees were wind-thrown.

Damage to the 2+2 white spruce seedlings in the largest clearcut is a major problem. The damage is on the currently flushing growth and resembles frost damage; however, other morphological changes below the dead tips suggest that an insect or other organism may be involved. Damage is most severe in plots that received early release, where practically every white spruce exhibits some damage. In the most severe cases, almost all of the actively growing tips were destroyed. Up to one-third of the 1 1/2 + 1 1/2 black spruce were damaged to some degree. Black spruce container stock was damaged the least. It appeared that any cover provided by adjacent vegetation reduced the amount of damage. Within the smaller clearcut blocks damage was considerably reduced, even in the early-release plots.

(D.H. Weingartner)

Quality of Second-Growth Aspen Stands

Two 40-year-old stands were sampled in cooperation with Dr. J. Basham of the Canadian Forestry Service, as part of a study to determine whether second-growth stands resulting from logging are of similar quality to those of natural origin. The stands involved are the oldest logging-origin stands sampled to date, and provide age overlap with naturally regenerated stands previously sampled in the same locality.

The two logging-origin stands had been sampled 10 years previously in another study. The previous sample indicated that stand A had slightly higher levels of defect, and had mean stem volumes nearly twice that of stand B. The current sample, on the other hand, suggests that mean stem volume and stem quality in stand A are considerably less than those of stand B. Complete analysis of the data will be carried out during 1987.

(D.H. Weingartner)

STAND MANAGEMENT

Hardwood

Sugar Maple Quality Dynamics

Logging Damage Studies:

Regression analysis of data collected from a cooperative study with Bracebridge District suggested that a good correlation existed between the proportion of basal area of residual trees which were damaged and/or wounded during logging and both the degree of ground disturbance associated with skidding, and the intensity of cut (percent of original basal area marked for removal). Effects were additive, indicating no interaction, and the regression equation explained 81% of the variation (Sy.x=13.3%). In the actual field data collected from 12 polar plots, skidding intensity (per cent of trail area) varied from 26.0% to 56.6%, cut intensity (per cent of marked basal area) ranged from 16.7% to 49.1%,and wounded and damaged basal area (per cent of residual trees) varied from 14.3% to 91.2%.

Three transects were set out in stands experimentally logged in 1985 in the Swan Lake Research Reserve. Logging practice was controlled within the study plots (ie. short-log skidding) and "normal" practice carried out in the surrounds. These transects will be used as baseline references for further cooperative studies of logging damage in Algonquin Region. Current work includes: i) using those detailed studies to suggest standards of acceptable logging practice in selection forests in order to maintain value growth, and ii) developing fast, efficient sampling methods to assess logging operations in terms of degree of damage to residual trees and site.

Assistance was given to the Algonquin Park District in developing a marking audit, sampling and analysis system for Algonquin Park. Polar plot mapping techniques developed from research methodology used at Swan Lake were adapted to monitor marking performance and subsequent logging operations, and ultimately to assess stand growth response. Computer programs to summarize this data as well as plot tree locations were written at Maple for this analysis, which includes both hardwood and softwood stands.

Tolerant Hardwood Ring-Width Study:

Using funds provided by the Ontario Ministry of the Environment, an analysis of 235 sugar maple trees from the Swan Lake Research data base was carried out to examine growth dynamics in logged stands. Growth (ring-width pattern) was compared over the period 1950-1980 among trees of different sizes and released to varying degrees in 1960.

Briefly, the analysis suggests that temporal trends in radial growth can be explained adequately using tree attributes (D.b.h., crown position, crown size, tree maturity index) and stand conditions (basal area stocking). Prior to release in 1960, most trees were growing at a similar rate (approx. 1.0 mm per year). Over the period 1960-1980, in the relatively undisturbed portion of the stand ($BA>22.5\ m^2.ha^{-1}$), tree size had little influence on radial growth rate, although the largest diameter classes were growing the fastest. However, the largest trees also showed the greatest relative decrease in growth rate over the 20-year period, suggesting that they represent the older, overmature, declining stand component.

There was a progressive response to degree of release with increasing initial D.b.h. ($10<22<36$ cm). The younger, upper-canopy trees showed the most response; however, the largest trees (>46 cm) were least affected by change in basal area (release). In general, ring-width for the 20-year period decreased as a function of the square root of initial residual basal area. Except for the upper-canopy trees given greatest release, and the larger unreleased trees, current growth rate of other classes was not significantly different from pre-release levels. Decreasing ring widths reflected either increased stocking levels or overmaturity, and were consistent with the concept of selection management as a tool for maintaining productivity.

Current work involves modelling this database for use in analysing the growth of yellow birch regeneration, and as a complement to other growth models developed for productivity purposes in Algonquin Region.

(H.W. Anderson)

Bill Beekers is marking trees for a selection cutting in a hard maple/yellow birch experimental plot at Swan Lake.

Growth of Tolerant Hardwoods after Commercial Selection Cutting

Management by Selection System:

At the request of Algonquin region, a new demonstration was established at Swan Lake to show selection management in hardwoods. One of the aims of this demonstration was to "bracket" the previously recommended residual stocking level of 60 square feet per acre with definitely lower and definitely higher residual stocking.

In this demonstration, 216 0.1-acre plots in groups of four were remeasured after cutting in winter 1985/86.

These plots were distributed between three replications of each of three different "residual basal area treatments"—40, 60 and 80 square feet per acre. "Control" plots were included. The treatments were such that the best-quality growing stock available was retained in the residual stand.

The stand was marked to the above specifications by Regional staff under the direction of the Research Forester, then was logged by a contractor for the Algonquin Forestry Authority.

Log-length skidding only was allowed in the study portion of the area; bole-length skidding was allowed in the fringe portion of the area,

a forest of distinctly poorer condition. The purpose of this arrangement was to ensure that the prescribed stocking levels could be created without excessive damage.

The plots will be remeasured at five-year intervals to document stand development under the various conditions created.

(M.M. McLean)

Development of Tolerant Hardwood Polewood after Pre-Commercial Thinning

Cutting of All Non-Crop Trees:

Data for 32 0.1-acre plots was examined and compiled to produce regression growth models for five, 10 and 14 years after thinning treatments.

The models are to be checked and a suitable format for publication is to be determined.

From the models produced, forest managers may be guided in their choices of residual stocking and length of treatment cycles.

(M.M. McLean)

Softwood

Balsam Fir: Growth and Yield

Balsam fir is assuming more importance for overcoming the shortage of conifer fibre in parts of northern Ontario as its stocking increases in relation to black spruce. Fir is not included in Plonski's normal yield tables or in the derived prediction models which are routinely used by management foresters. Fir growth-and-yield information is commonly estimated by substituting values from the black spruce tables. This study examines the validity of this practice.

Fifty 0.04-ha plots in polewood fir stands were measured with partial destructive sampling to obtain the actual gross total volume (GTV) and current annual increment (CAI). The estimated GTV and CAI were also obtained for each plot by conventional application of Plonski's black spruce yield tables. The reliability of the estimates was tested by regression over the actual values and by applying a chi-square test of accuracy.

The relationship between the estimated and actual values is strong for GTV (R^2 = 0.90), but much weaker for CAI (R^2 = 0.21). Accurate estimates of standing volume can be obtained by application of Plonski's black spruce yield tables to fir stands. However, considerable random error and systematic bias arise from the inherent difference in growth rate between the two species, and invalidate yield-table substitution for balsam fir increment determination. It is recommended that fir growth models adaptable to local stand and site conditions be developed as a more reliable basis for management planning.

(G.B. MacDonald)

Growth Models to Refine Tending of Boreal Conifers

Productive upland boreal sites often support a complex structure of competing tree species. Mixedwood tends to persist following harvesting and planting to conifer; aspen, birch and fir invade agressively even where those species were not present in the stand before it was harvested. The goal of this study is to model the productivity and stand dynamics of the commercially important species as a basis for tending guidelines in natural stands and plantations.

Eleven 0.2-ha plots containing approximately 7 000 trees in total were established in pole-sized mixedwood stands of natural and plantation origin. Individual stems were mapped and their volumes back-projected by stem analysis. This database is the input for computer models which relate the productivity of each species to stand structure.

Current analysis is concentrating on the development of competition indices for each species. The most effective indices incorporate the size and proximity of neighboring crowns, indicating that light is the limiting resource for all species tested. In general, volume growth is more sensitive than height growth to competition level, and the responses are clearer for aspen than for spruce or fir. The next stage of analysis will incorporate the competition indices into simulation models to define the most productive mixedwood structures. These stand structures will be management options in the proposed tending guidelines.

(G.B. MacDonald)

Thinning Aspen in the Boreal Mixedwood Forest: Growth and Yield

Six aspen stands, aged five to 20 years, were systematically thinned between 1979 and 1981. Following the fifth-year assessment, the mean tree volume in the thinned plots is approximately 30% greater in the 10-year-old stand and 20% greater in the 15-year-old stand than in the control plots. The increased volume of the thinned trees is primarily due to an increase in diameter growth, which agrees with the published results of others.

Aspen height growth has been reported, in the literature, to be either reduced or not influenced by thinning. Summarization of the fifth-year data from the three five-year-old stands indicates that mean height is reduced incrementally as the space between the trees increases from two metres to five metres, indicating a possible thigmomorphogenic response. Compared to the controls, mean height of the thinned plots was reduced in two of the stands and stimulated in the third stand. A definitive cause for the stimulation of height growth in the third stand has not been identified; however, it is suspected that the response is due to increased soil moisture availability, where that may have been a limiting factor. Mean annual precipitation in the area of the third stand is approximately 15 cm less than that at the other two stands.

The 20-year-old stand was reassessed for the fifth year, and the data was entered on computer. Data summarization and preliminary analysis are scheduled for 1987. A preliminary look at the fifth-year

data suggests that the diameter increment of the thinned trees is approximately twice that of the control trees.

(D.H. Weingartner)

Biomass Culture and Silviculture

Biomass Culture and Silviculture on Upland Sites: Southern Ontario

Southern Ontario is predominantly hardwood country. The soils are productive and highly accessible, comprising about 3.6 million hectares of forest land including marginal agricultural areas. The upland sites support a wide range of fine deciduous tree species such as black walnut, oak, maple, black cherry and yellow birch, and include admixtures and plantations of valuable softwoods such as white and red pine.

Gradual deterioration and changes in the composition of the original forest cover of southern Ontario may be attributed to a series of factors such as indiscriminate initial land clearing followed by excessive industrial demands and unregulated exports of top-quality timber.

Other factors include biological adversities such as outbreaks of chestnut blight and epidemic decimation of elm (once the principal component on the highly productive lowland sites), and insufficient provision for optimum forest management consistent with sound environmental practices.

Recently, in spite of a scattered ownership pattern, incentives for expanding forest enterprises appreciably increased, mainly as a result of cohesive opportunities provided by the Woodlands Improvement Act (WIA). Rapid technological advancements and changes in utilization practices, as well as the demographic and ecological requirements of a progressively expanding population, have also contributed to greater forestry opportunities in Southern Ontario.

The main objectives of the silvicultural and biomass studies are presently directed at:

- identification, quality improvement and mass propagation of fast-growing stock
- optimal regeneration of upland hardwoods and associated species on submarginal agricultural land and in understocked, high-graded woodlots
- development of optimal forest management techniques within the framework of a coordinated program strategy.

(P. Jaciw)

Modeling Biomass Accumulation in Mini-Rotations

The International Energy Agency has invested a lot of research effort in mini-rotations of fast-growing hardwood species that coppice actively, as a potential solution for a future energy crisis. As yet, though, no instrument is available for estimating the potential biomass production which could be expected from such systems.

A clone x irrigation-rate experiment established in 1982 and managed on a two-year rotation has yielded information well beyond its initial

scope, leading into the area of modeling of biomass accumulation. Biomass accumulation was calculated daily for a "standard crop", based on the well-recognized de Wit model, using as input variables: daily sums of photosynthetic active radiation; air temperature; and atmospheric saturation deficit. The daily values were accumulated between the "start" and "end" of the growing season, determined by phenologic observations. For most black hybrid poplar, the start would correspond with an average daily temperature of over 10°C for more than five days, where the end normally occurs after five days with an average daily temperature of less than 5°C. The photosynthetic production was corrected for air temperature effects according to an exponential function of temperature in the interval 10°C to 30°C. Comparison between simulated and harvested woody biomass is given in Table 3.

TABLE 3 Potential production of standard crop compared with harvested biomass (oven-dry tons/hectare)

Item	1983	1984
Dry matter production (simulated)	11.168	12.920
Harvested biomass		
- clone Baden-431	2.650	14.020
- clone Unal-8	2.300	11.330
Ratio Harvest/DMP		
- clone Baden-431	0.237	1.085
- clone Unal-8	0.206	0.855

DeWit's estimate of simulated dry-matter production represents about four times the woody biomass accumulation of the mini-rotation in the first year, mostly due to the insufficient radiation captured by the foliage. However, in the second year of the cycle, the harvested production came very close to the standard. In that year, the plantation already had a leaf area of two at complete foliation, which increased to about seven at the end of the growing season. An almost complete absorption of the photosynthetic-active radiation in the second year assured a ratio of harvest to dry-matter production of standard crop of around one.

Calculated dry-matter production can serve to compare the potential photosynthetic production of various years or localities. Due to varying clone performances, the ratio between harvested biomass and DMP will not equal unity for every clone, though a clonal or genetic correlation could be established in trials of widely used clones and built into the model.

(C.S. Papadopol)

Environmentally Sound Effluent Disposal

Over the past five years, a project which combines effluent recycling with intensive silviculture was developed on the grounds of Seneca College in King City. The cooperative project was initiated because an increased college population was overloading available facilities for waste water disposal, forcing the college to consider building another storage lagoon and adding to the spray area.

Based on previous studies of evapotranspiration, poplar irrigation for growth stimulation, and effluent disposal on poplar plantations in Ontario, a large poplar and willow plantation was established in stages (1983-1986), replacing the grassed spray area. The assumption was made that the large, developed foliage of intensively cultivated poplar would have a considerably increased rate of transpiration and a much greater nitrogen reprocessing ability than grass. The plantation was established at 4 m x 4 m intervals, keeping in mind its potential use as a sludge recycling area; enough space was left for a mechanical sprayer to circulate along the rows of trees. Wind penetration of the canopy, even partial, was expected to enhance the consumptive use of forest. Branches are pruned annually to maintain this function after canopy closure.

The plantation was conceived as a clone trial superimposed on an existing solid set of sprinklers and underground pipes. Poplar clones cover a wide range of intra- and inter-sectional hybrids. Depending on their growth and other characteristics, it will be possible (perhaps around age 10) to define a poplar ideotype suitable for waste water reprocessing.

Willow was planted on the lowest spots, some of which are more than 200 days a year under water. European alder of various provenances was included in more recent plantings.

For the Seneca project, the inclusion of plantation technology in a waste water treatment facility was conceived differently than for the numerous waste water disposal projects involving North American forests. This difference consists in the elaboration of an environmentally sound recycling procedure based on a huge consumer which is fed with effluent at rates corresponding to atmospheric demand for evapotranspiration. A plantation of this kind would receive irrigation equal to the climatic demand, which varies from one day to another. Figures 1 to 4 opposite display the variation in atmospheric parameters and potential evapotranspiration for a cloudless day and for a cloudy day in the summer of 1986. Operated in this manner, such a plantation would dispose of effluent only through transpiration, truly accomplishing a role of "living filter" and preventing groundwater contamination.

Apart from its local importance for small communities in Southwestern Ontario, variations on this concept could prove of exceptional importance for Third World countries. In general, these countries are situated in dry areas with longer growing seasons than Ontario; fuel shortages are sometimes more acute than food shortages. Adoption of a system of waste water reprocessing would allow fast fuel production, on a sustained basis, of species that could be coppiced. The richness of domestic waste water from crowded urban areas could significantly enhance trees' growth rates because of the synergistic effect on growth where water and nutrients are applied regularly and abundantly. This solution, which interpolates a vegetation link in the reprocessing of waste water, may prove superior to one currently applied system in South-East Asia in which raw human waste is fed to fish. Through the simple chain human waste—fish—human food, disease epidemics can spread easily; in a system human waste—tree—fuel biomass, with the effluent contained, risks are almost completely eliminated.

(C.S. Papadopol and P. Jaciw)

FIGURES 1 TO 4

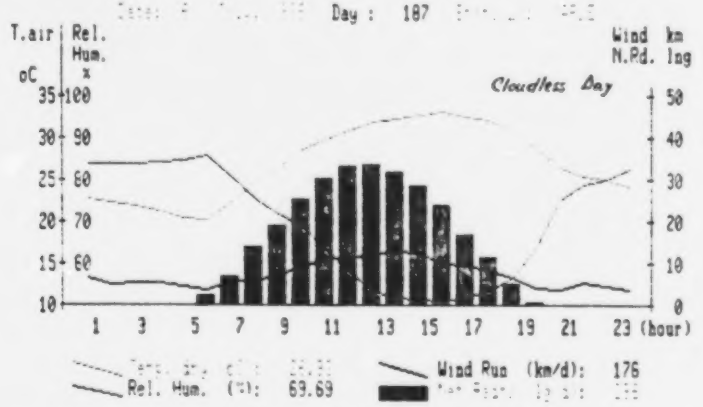


Fig 1. Hourly variation of Temp., Rel. Hum., Wind and Net Radiation

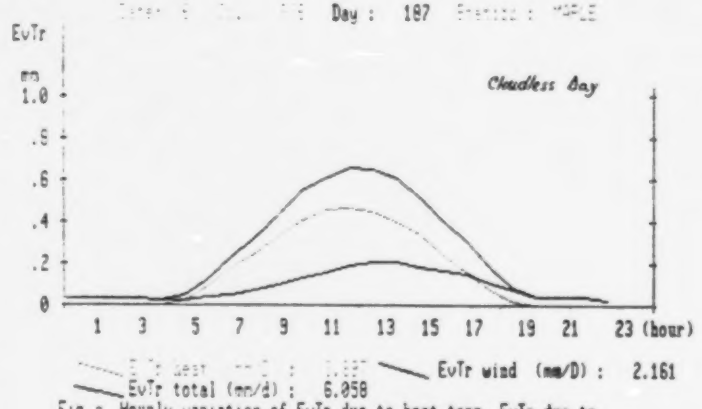


Fig 2. Hourly variation of EvTr due to heat term, EvTr due to aerodynamic term and DAILY TOTAL EvapoTranspiration

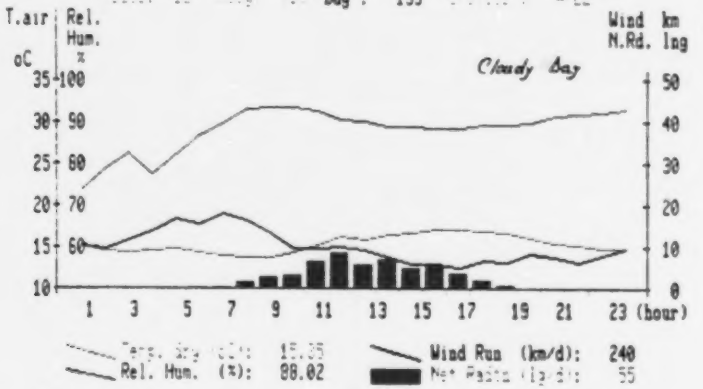


Fig 3. Hourly variation of Temp., Rel. Hum., Wind and Net Radiation

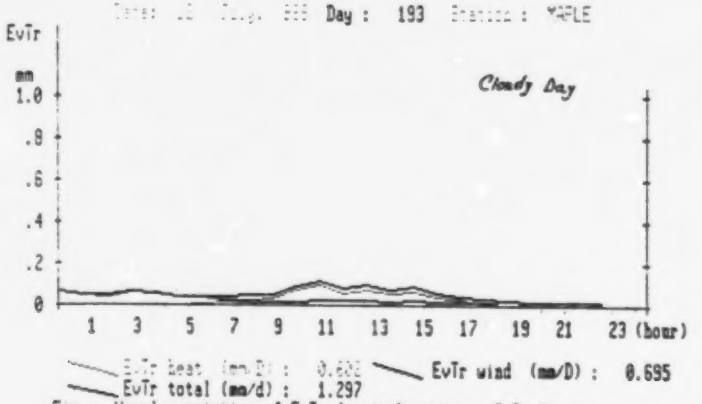


Fig 4. Hourly variation of EvTr due to heat term, EvTr due to aerodynamic term and DAILY TOTAL EvapoTranspiration

Effluent Polishing in a Planted Ditch/Mound System

Waste processing poses a considerable challenge to modern food-processing industries, with their seasonal operation and restricted raw-material base. Effluent produced by cannery activity tends to be uniform and related to product type. Effluent from vegetable processing industries is characterized by very low or absent heavy-metals content and high chemical oxygen demand: it is thus well suited for land treatment but presents odour problems if disposed of by sprinkler irrigation over agricultural crops.

Until 1981, the Hardee Farms International plant in Lambeth, Ontario, (currently Cobi Foods), was active only in the summertime, when it processed frozen peas and corn. It disposed of its effluent through sprinkler irrigation on a cornfield. With the addition of wintertime production of french fries, the volume of effluent increased significantly, and its composition changed to the extent that the plant began to receive numerous complaints from encroaching housing developments about effluent odour.

Anne Pratchett measures the growth of a rust-resistant hybrid poplar clone from Belgium.

To resolve the problem, the waste treatment facilities of the plant were revamped, and sprinkler irrigation was replaced with an innovative land-treatment procedure based on a ditch/mound system planted with hybrid poplar clones and black willow. The 2-ha system was made by profiling the land into six mounds spaced 12.5 m apart (centre to centre) to create seven ditches with a North-South orientation. As the effluent moves slowly through the ditches, suspended solids settle. During the growing season the effluent is partially consumed by the irrigation needs of the poplar plantation. Maintaining a constant level of effluent in the ditches has created a capillary fringe of effluent in the vadose zone inside the mound, where unique conditions foster active decomposition. A link in a new treatment technology, the system falls between the storage lagoon and the discharge creek.

The performance of the ditch/mound system was closely monitored in terms of tree development as well as treatment effectiveness. Poplars planted on the mounds were in a very favourable situation: water availability was unhampered, unlimited nutrients resulted from waste decomposition in the vadose zone, and soil aeration, a key factor for active poplar growth, was secured. The growth performance of trees is given in Table 4 below.

TABLE 4 Average dimensions of poplar clones at the end of the growing season from 1983 to 1986

Clone	No. of Trees	1983	1984	1985	1986
		Total Height (m)			
DN-2	376	1.19	3.23	4.97	6.56
DN-5	372	1.10	2.73	4.15	5.86
DN-55	379	1.31	3.38	4.98	6.56
NM-6	385	1.32	3.25	4.97	6.60
		Diameter at Breast Height (cm)			
DN-2	376	Not	2.48	4.50	6.74
DN-5	372	measured	1.69	3.47	5.63
DN-55	379	in 1983	2.43	4.35	6.75
NM-6	385		2.13	4.06	6.78

The ditch/mound system has proven highly effective. Crude flow tests have shown over 40% reduction of flow, due mostly to transpiration. Removal of NH_3, chemical oxygen demand of effluent, and phosphorus were 60%, 52% and 41%, respectively, with high-strength effluent. Overall, the system has shown a high ability to deplete the effluent of its organic load and to absorb the resulting nitrogen into poplar leaf biomass. Effluent output was depleted of its suspended and dissolved loads without odour creation. Over time, the effectiveness of the ditch/mound system is expected to increase; monitoring should continue over the next few years.

The operational success of the ditch/mound system shows how species' requirements may combine with conditions created inside the mounds to achieve superior and cost-effective waste water recycling.

(C.S. Papadopol and J.D. Nolan)

Application of Dendrometer Techniques to Stand Tending

Seasonal growth patterns and annual increments were monitored with dendrometer tapes at bi-weekly intervals on juvenile red oak established with and without hybrid aspen nurse crop. Annual temperature and precipitation variations proved to be less significant for the growth of oak than for aspen. This finding could be ascribed to the difference in rooting habits of the two species. Phenological development appeared to be influenced appreciably by the presence and type of nurse crop.

Similar dendrometer techniques were used at weekly intervals at Maple on red pine, white pine and white spruce. In contrast to juvenile hardwoods, diameter increments of the above conifers showed a significant correlation with prevailing atmospheric conditions and particularly with frequency and amount of precipitation.

Dendrometric methods have been applied throughout the season to a sample of over 200 poplars comprising over 50 select cottonwood and hybrid aspen cultivars. The clones were planted under severe physiographic conditions at high elevations of Dundalk Highlands to determine their general performance: increment rates, growth culmination, cold hardiness and pathogen resistance. In the fall, a complete survey of the Deltoides/Nigra clonal trial was completed. This included measurements of D.b.h and height, and assessment of quality, form, and branch and stem pathogens. Results suggest that seasonal dendrometric monitoring can contribute appreciably to the early assessment of young cultivars and species and can help in the identification and selection of ideotypes for specific conditions.

Work was continued on the thinning of a 3-ha maple-basswood-ash polewood stand. Seasonal growth was recorded on over 200 sugar maple in heavily thinned, lightly thinned and control plots near Chatsworth, Ontario, using modified Liming-type dendrometer bands. The tape design was modified by the Unit to take diameter measurements of trees as small as one inch D.b.h. Presently, there is sufficient indication that although the relative differences among the three stand-density treatments remained relatively unchanged, the growth rate has progressively diminished, showing appreciable correlation with microsite conditions rather than with treatment area.

(P. Jaciv)

Dendrometer Techniques in Monitoring Ecological and Silvicultural Conditions

Diameter increments at breast height were monitored for red pine throughout 11 growing seasons, from age 12 to 22, using modified dendrometer tapes. Increment readings were taken at approximately bi-weekly intervals of individual samples of pruned and unpruned red pine spaced at 1.8, 2.7 and 3.7 m (6, 9, 12 ft) comprising a total of 240 trees.

Initially, the main effect of pruning was a relative decrease in lower stem diameter: the wider the spacing, the more pronounced the effect. Progressively, the low-intensity pruning contributed to improved growth, clear bole, reduced taper and better wood quality.

FIGURE 5

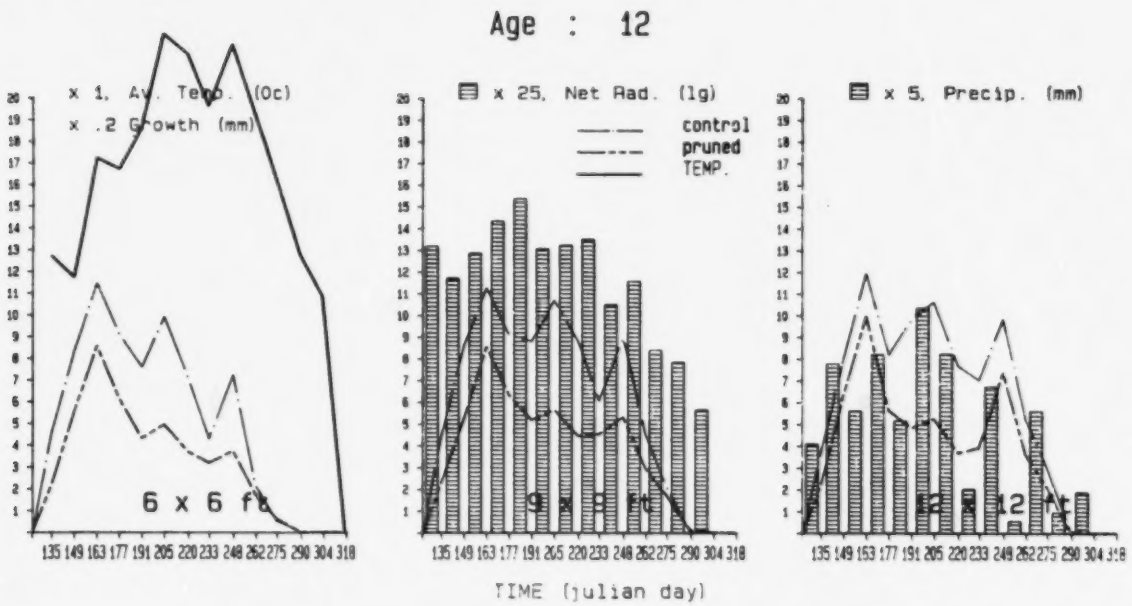
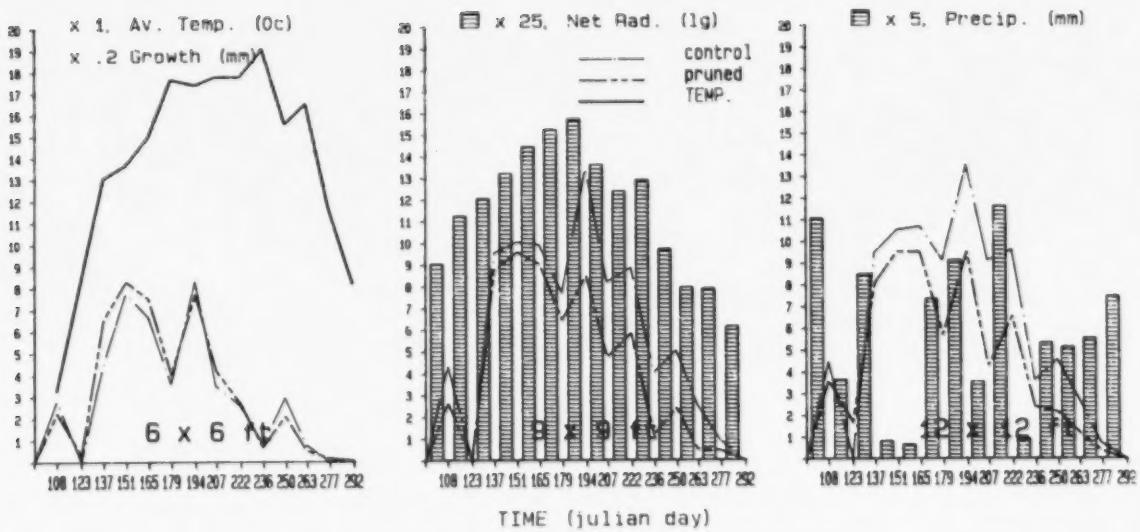


FIGURE 6



Daily variation in growth related to temperature and precipitation during the growing season.

Removal of fully active branches at any spacing reduces the photosynthesizing crown and should not be practiced, but ought to be adjusted to the specific crown-energy relationship of trees at individual densities.

The reduced taper and clear bole, a result of progressive low-intensity pruning, should enable the tree to be grown at a wider spacing and produce better quality stemwood with relatively less mill waste.

Atmospheric records correlated with the annual growth patterns of trees in the individual treatments showed that:

- the length of red pine growing season relates closely to temperatures in the spring and temperature/precipitation in the fall;
- the rapid growth rates of early spring show almost no fluctuations and only minimal differences among treatments;
- the diameter increments generally peak prior to the midpoint of the growing season;
- the following variations in short-term growth rates relate mainly to evapotranspirational demands;
- the trees in the closest spacing appear highly susceptible to late summer atmospheric stresses, demonstrating their sensitivity by appreciable and rapid growth reactions (see bar graphs, Figures 5 to 6, page 53).

Using dendrometers for monitoring current tree growth helps to optimize stand performance related to treatments, site, species and ecological influences. The method has wide applicability in research and operational projects contributing to the establishment of sound scientific foundations for intensive stand management.

(C.S. Papadopol and P. Jaciw)

Strain Gauges for Tree Growth Measurement

For a long time, growth modeling studies have needed a continuous and non-destructive tool sensitive enough to detect hourly variations in the diameter of trees and amenable to automatic recording. The strain gauge, a device widely used in various fields of measurement technology and experimental stress analysis, appears to meet this need. The strain gauge operates on the principle that metal alloys experience an increase or decrease in resistance when stretched or compressed. A strain gauge glued on smoothed bark of a tree will record changes in circumference induced by the environment so that diameter variation can be monitored.

Ten white pine trees were equipped with strain gauges connected to a data collection system that scanned them hourly through a four-arm bridge. Weather data was obtained at the same intervals from an automated weather station located in an open field about 100 m from the stand of trees. The system operated during the growing season of 1986.

Stem fluctuations follow a pattern of diurnal stem contraction strongly related to environmental factors such as solar radiation, temperature, air saturation deficit and soil water stress. Strain fluctuations were very similar among the 10 trees investigated. As a magnitude they were a function of diameter: thicker trees expanded or contracted more than thinner trees. During a typical cloudless day in mid-growing-season, a contraction became apparent at 10 a.m. and continued until around 6 p.m. At that hour, the tree diameter was always

smaller than in the morning, an effect of the transpirational demands, which during a cloudless day are known to proceed at greater rates than root water extraction. In the evening and during the night, the strain gauges displayed diameter expansion to reflect both stem rehydration and redistribution of photosynthate. During the growing season, the strain value in the early hours of a day were always greater than the day before, given similar conditions. The difference is the effective growth.

Preliminary research results show the strain gauge method to be an effective, sensitive and adaptable tool for investigating environmental influences on trees, including short-term influences such as an acid event. Accurate growth measurements are possible with this method.

(C.S. Papadopol and P. Jaciw)

Modeling the Environment-Growth Relationship

A great deal of work is being done around the world on the development of management-oriented forest growth models. For the intensive, cultivated forest, individual tree models based on spacing and competition are valuable; after an intervention such as thinning, the stand assumes a quasi-steady-state situation until the next intervention.

Since trees preserve a "record" of integrated environmental effects, it should be possible to correlate annual growth with synthetic indices of the environment. Such efforts may provide information for intensively managing prime-quality stands, in effect allowing experimentation with management alternatives, and ultimately with economic benefits. Specific models may incorporate assumptions about clonal behaviour or response mechanisms such as competition. They offer an objective means for assessing the "quality" of certain prime sites or the favourability of environmental conditions for certain species.

In order to develop the basic statistical relations for a mechanistic stem growth model with a major environmental component, information obtained with the Tree Ring Increment Measurement System (TRIM) was used in conjunction with the soil water transport model. TRIM was used to determine the annual stem volume growth of several sample trees chosen from a spacing experiment with red pine, a poplar clonal test, and a mixed pine-oak plantation. The soil-water transport model was used to assess water availability through an index derived from the suction head. Inputs to the model included weather elements determined through the climatic network and locally measured soil hydraulic conductivities. The model was run for various intervals for each of the above-mentioned growth data sets, during intervals conventionally considered as the local growing season, assumed to begin five days after the air temperature climbed to a certain threshold (T start) and to end five days after the air temperature dropped below a certain level (T end). (T start was 0°C for pine and 10°C for poplar and oak, while T end was 0°C for pine and 5°C for poplar and oak.) The synthetic environmental index thus generated was correlated with stem volume growth.

Analysis of preliminary results has shown that stem growth is highly responsive to the "favourability" of the growing season. In absolute values, this response is greater in poplars, particularly for the clone I-214. Red oak appears to reflect strongly the continued effects of the major limiting factors of temperature and water availability. Stem growth is strongly related to the number of daytime hours when the

suction head of soil water was less than 0.5 atm. for the layer of soil between 0.5 m and 1.0 m. Growth can also be related to an index of precipitation regularity during the growing season.

Through refining the assumptions for the soil water transport model and gathering more data with the TRIM system, it will be possible to predict species performance on specific sites better than through stand development curves, where growth is just a function of time. The more weight given to weather elements and physiological processes as driving variables for the model, the greater will be the proportion of explained year-to-year growth variability, the ultimate source of the predictive power of this tool.

(C.S. Papadopol)

SITE

Regional Ecology

Currently the main emphasis of this program is on the recognition, characterization, mapping and description of site regions. These regions are characterized by specific relationships between the distribution of tree species and land form positions. Differences among regions are an expression of the effect of macroclimate on these relationships.

Site regions represent the broadest level of the Ontario physiographic site classification system, which has been developed by Ontario government site specialists over the last 40 years. These regions, when properly used, will help to reduce the risk of management error. For example, site regions have been used as seed zones and could guide the introduction of species. Regional boundaries suggest limits within which specific silvicultural prescriptions for similar ecosystems apply, but beyond which adjustments would need to be considered seriously. Because site regions indicate broad levels of potential productivity (as governed by microclimate), they have been useful for land inventories, while providing a province-wide broad framework for data collection and interpretation for land use planning and forest inventories.

Site Regions of Ontario

New information and experience have been accumulated since publication of the last version of Site Regions of Ontario in 1966. This project has now two parts: i) to consolidate and clarify concepts and principles, and ii) to describe techniques used in the characterization and delineation of site regions. This will facilitate the recognition of site regions beyond Ontario by other researchers. The second part will be to update the description of relationships between tree species in relation to land form positions. Information on climate will be included and adjustments made to the characterization of regions and their boundaries. Manuscripts dealing with both objectives are in preparation.

(D. Burger)

Ecoclimatic Regions of Canada

The concept of site regions as developed in Ontario has been included in the development of "Ecoclimatic regions of Canada". This

project was undertaken by the Ecoregion Working Group established in 1978 under the auspices of the Canadian Committee on Ecological (Bio-Physical) Land Classification. This is a volunteer group of federal and provincial researchers. Contributions to a map (scale 1:7 000 000) and to regional descriptions have been finalized and the draft report and map are now with the Canada Lands Directorate for editing and publication.

(D. Burger)

Site Regions of Northeastern North America

The purpose of this project is to extend the site regions of Ontario and the comparable ecoclimatic regions of Canada southward into the United States, and thus provide a useful continental ecological framework for the exchange of biological and silvicultural knowledge and of plant materials. The status of this long-term project as described in the 1983-1985 Research Review has changed little, because higher priority was given this year to other work. However, some new field observations and new publications have added to the data base.

(D. Burger)

Regional Forest Ecology, Northeast China

A manuscript entitled "An introductory comparison of forest ecological conditions in northeast China and Ontario, Canada" was written in cooperation with Mr. Zhao Shidong of the Institute for Forestry and Soil Science, Chinese Academy of Science, Shenyang, Liaoning Province, People's Republic of China, and has been submitted to reviewers. The writing of the manuscript was enhanced considerably by field experience obtained by this author during his visit to these areas in northeast China in July. These visits included field trips and the presentation of a paper ("Physiography as an integral part of forest ecosystems") at the International Symposium on Temperate Forest Ecosystem Management and Environmental Protection in south eastern Jilin Province. There were also a consultation for CIDA (see below) in northeastern Heilongjiang Province and field trips east of Shenyang in Liaoning Province. The next phase of this project includes seeking cooperation with Chinese researchers to establish and describe site regions in northeast China and further south analogous to those of Ontario.

(D. Burger)

Consultation, Land Classification,
People's Republic of China (PRC)

This author was on a two-week contract in July with T.M. Thomson & Associates Ltd., consulting engineers and foresters of Victoria, B.C., to participate in the CIDA-PRC's Integrated Intensive Forest Management Project in the Langxiang Bureau (northeast of Harbin), Heilongjiang Province. A report entitled "Notes on forest soil and forest ecology, Langxiang Forest Bureau" submitted to Thomson & Associates Ltd. deals with altitudinal zones (400-1 200 m a.s.l.), translation of the Chinese legend to a recent soil map (scale 1:100 000) of the Bureau, recommendations regarding soil and site classification, comments on preliminary ecological forest type tables, and evaluation of the suitability of a local peat for use in growing container seedlings. A lecture on site classification given to a large group of local forest farm technicians was a challenge in communications.

(D. Burger)

Alison Curtis, Larry Spence, Linda Packer and Marie Ashworth use this nitrogen distillation unit to measure the nitrogen in the soil.

Forest Ecosystems

Productivity and Nutrient Cycling in Spruce Forest Ecosystems

Improvement in nutrient budgets construction continues, as data on specific runoff and the deep sink water, as well as data on nutrient distribution and flux, gradually accumulates. Lysimeters and soil-porous cups which are used in these studies have the advantage that they precisely define the conditions in the stands where they are located. They are, however, difficult to maintain, and require a great deal of attention, particularly at freeze-up and thaw. Wiers, on the other hand, effectively measure water leaving a watershed. Most watersheds of moderate topography contain a small or large array of forest types which vary widely in chemical budgets and nutrient distribution strategies. Wier data collected in areas of gentle topography synthesize all these variables: stand type, soils, etc. They are particularly affected by non-representative riparian stream-side vegetation and sites, and are in consequence most useful in mountainous or other topographically steep landscapes.

Information is also accumulating in these studies on inputs and transfers of sulphate and nitrates along with that of principal nutrient elements in order to determine any possible negative effects of acid precipitation. This information is to be used comparatively with U.S. scientists also working on spruce-fir forests.

In productivity studies, we have provided information on specific gravity of spruce in relation to forest site to British scientists (Cannell, M.G.R.) for use in worldwide studies of specific gravity in forest tree species.

Data collection was completed on a study which should enable us to build a model for non-destructive sampling of individual spruce genotypes growing in plantations. It should also be useful for rapid non-destructive sampling in managed stands of spruce. Half the data comes from unsuppressed young black and white spruce growing in natural stands, about 45 trees. The second half comes from samples of 21 trees each of 13 selected genotypes (a total of 273 trees) growing in a Picetum. This data, consisting of foliar mass, branches, boles, growth measurements and specific gravity, along with our previous baseline data, should enable us to calculate actual productivities much more efficiently than heretofore. The method, when finalized, should also constitute a very useful management tool.

Finally, additional spruce-fir plots in heavily budworm-defoliated stands on the east side of Lake Superior were re-examined and measured. This data further confirms our findings with respect to the excellent survivorship of white spruce in heavily defoliated white spruce - fir stands as indicated in our spruce-fir stand dynamics model. The infestation was maximal. All the mature and immature balsam fir are totally dead, while the white spruce are currently building their crowns and starting to flower. There will still be ample balsam fir regeneration, however, rising from very small seedlings present on the ground.

(A.G. Gordon)

PAPERS AND POSTERS PRESENTED

Anderson, H.W., C.P. Chen and K.A. Roberts. Hybrid Poplar Energy Farms. I.E.A. Tree Nutrition Workshop, Kingston, Ontario. (Poster)

Anderson, H.W., A.G. Gordon and M.M. McLean. Swan Lake Forest Research Reserve. Tour Guide prepared for OTiFBI Scientific Review.

Anderson, H.W., J. Rice, K. Roberts,and W. Beekers. Maintaining a yellow birch component using group selection. Managing Northern Hardwoods Silvicultural Symposium, Syracuse, New York. (Poster)

Balatinecz, J.J. and H.W. Anderson. Some effects of climatic factors on the formation of wood and its quality. Forest Climate 1986 Symposium, Geneva Park, Ontario. (In Press)

Burger, D. Provisional site regions of eastern North America: the effect of macroclimate on tree species-site relationships. Forest Climate '86 Symposium, Geneva Park, Orillia, Ontario. 17-20 November 1986. (Poster)

Colombo, S.J. Root hardiness, Extended Greenhouse Culture and frozen storage of container stock. Presented at regional container stock technical meetings: Dryden, Ontario, 29 July 1986; Thunder Bay, Ontario, 30 July 1986; Timmins, Ontario, 12 August 1986.

Colombo, S.J. and G.S. Jackson. Assessing moisture status in tree nurseries and forest plantations using the pressure chamber. Forest Climate '86 Symposium, Geneva Park, Orillia, Ontario. 17-20 November 1986. (Poster)

Colombo, S.J., K.D. Odlum and C. Glerum. Measuring and improving the physiological quality of planting stock. Stock Production Development Activity Seminar, Timmins, Ontario. 1-4 December 1986.

Glerum, C. Some physiological aspects of plantation establishment. Northwestern Region Silviculture Information Session. Kenora, Ontario. 17-19 March 1986.

Glerum, C. and J.M. Paterson. Climatic influences on jack pine and black spruce growth during eight growing seasons after planting on a dry and a fresh site in a northern Ontario cutover. Forest Climate '86 Symposium, Geneva Park, Orillia, Ontario. 17-20 November 1986.

Glerum, C., J.M. Paterson and G.D. Racey. Stock standards for early plantation establishments. Stock Production Development Activity Seminar, Timmins, Ontario. 1-4 December 1986.

Ho,R.H. In vitro culture of tree species. Biotechnology for Ontario's Forests, Plant Biotechnology Centre, University of Guelph. 5 April 1986.

Ho,R.H. In vitro culture of spruces. Conifer Biotechnology Day, Plant Biotechnology Institute, NRC, Saskatoon. 24 September 1986.

Ho,R.H. Cone Induction Research at OTIFBI. Breeding Hall Working Group, G. Howard Ferguson Tree Nursery, Kemptville. 3 March 1987.

Ho,R.H. Sex in Conifers. Seminar at OTIFBI. 7 January 1986.

Ho,R.H. Tissue Culture. Seminar at OTIFBI. 27 February 1986.

Ho,R.H. and A.Y. Raj. Poster. In vitro culture of explants from mature black spruce and jack pine. Biotechnology for Ontario's Forests, University of Guelph. 5 April 1986.

McClain, K.M. The role of seedling quality in plantation establishment. Silviculture Information Session, Northwestern Region, Kenora, Ontario. 17-19 March 1986.

McClain, K.M. The importance of conditioning nursery seedlings to improve field performance. Symposium on Stock Production, Northern Forest Development Group, Timmins, Ontario. 1-4 December 1986.

Odlum, K.D. Greenhouse cultural regimes for rapid bud initiation. Regional container stock technical meetings: Dryden, Ontario, 29 July 1986; Thunder Bay, Ontario, 30 July 1986; Timmins, Ontario, 12 August 1986.

Odlum, K.D. and S.J. Colombo. The effect of night temperatures on bud initiation in black spruce seedlings. Stock Production Development Activity Seminar, Timmins, Ontario. 1-4 December 1986.

Odlum, K.D. and S.J. Colombo. Thermoperiod control of bud initiation. Forest Climate '86, Geneva Park, Orillia, Ontario. 17-20 November 1986. (Poster)

Paterson, J. Red pine plantation establishment. Northwestern Region Silviculture Information Session. Kenora, Ontario. 17-19 March 1986.

Paterson, J. and C. Glerum. Good planting pays. Renewable resources grant seminar. Poster handout at COJFRC Information Session. (Poster)

Raj, A.Y. and R.H. Ho. Cloning of spruce and pine germinants through in vitro culture (Poster). Biotechnology for Ontario's Forests, University of Guelph. 5 April 1986.

UNIVERSITY INVOLVEMENTS

Anderson, H.W.

Coordinated fourth-year course at University of Toronto in Advanced Silviculture and Ecophysiology.

Member of search committee for recruiting new silviculture professor at the University of Toronto.

Examiner on thesis defense for three graduate students (two MScF, one PhD) at the University of Toronto.

Lectured University of Toronto students in Forest Products (fourth year) and Silviculture (third year and fourth year).

Presented graduate seminar at University of Guelph on Agroforestry.

Committee member for PhD graduate student at University of Guelph.

Buchert, G.

Adjunct Professor, University of Guelph. On advisory committee for two MS candidates and one PhD candidate.

Glerum, C.

At the Faculty of Forestry, University of Toronto, serves on supervisory committee of two MScF candidates.

Gave a two-hour lecture on coniferous plantation establishment to fourth-year University of Toronto students in January.

Gave a two-hour lecture on planting stock quality to third-year students in October.

Gordon, A.G.

Gave a lecture on "The dynamics of the spruce-fir forest and its relation to the budworm" at the Faculty of Forestry, University of Toronto, 27 January 1986.

Gave a lecture on "Morphometrics and taxonomy of red and black spruce and their hybrids" at the Dept. of Forest Resources, University of New Hampshire, Durham, NH, 10 December 1986.

Ho, R.H.

On advisory committee for graduate student, MSc program, Faculty of Forestry, University of Toronto.

Presented a lecture on "Biotechnology in forest genetics and tree breeding" at the Faculty of Forestry, University of Toronto, 19 March 1987.

McClain, K.M.

Appointed Adjunct Professor to the School of Forestry at Lakehead University.

Presented a discussion paper on Regeneration Physiology to fourth-year degree students.

Acted as Scientific Authority to COFRC- and RRGP-funded projects dealing with seedling conditioning and outplanting performance.

Contributed to formulation of MScF theses topics on various aspects of cultural practices in nursery and seedling water relations.

Member of the Lakehead University Forestry Advisory Committee.

Skeates, D.A.

Presented two lectures, one on conservation of genetic resources and one on forest tree seed, in a noon-hour series at the Faculty of Forestry, University of Toronto. Also provided assistance in a postgraduate course on Social Forestry, using some of the resources obtained during a 1985 secondment in Southeast Asia.

COMMITTEES

Anderson, H.W.

Maple Complex Woodlot Committee (Ontario Ministry of Natural Resources).

Maple Syrup Research Committee (Ontario Ministry of Agriculture and Food).

Buchert, G.

Member, Canada-Ontario Joint Forest Research Committee

Member, COJFRC working group on Tree Improvement

Member, COJFRC working group on Resistance of Trees to Pests

Member, OMNR working group on Clonal Forestry/Rooted Cuttings

Member, Abitibi-Price working group on Jack Pine

Member, Evaluation Team, for evaluation of Eastern Region Fast Growing Hardwoods Group

McClain, K.M.

Member of organizing committee for the Symposium on Nursery Stock Production sponsored by the Northern Forest Development Group, Timmins, Ontario, held 2-5 December 1986; appointed member of Steering Committee to deal with recommendations arising out of the Symposium.

EXTERNAL CONTRACTS

Whitehouse, K.

1986 Tolerant Hardwood Ring-width Study. $5,000.00. (Funded by the Ontario Ministry of the Environment).

OTHER ACTIVITIES

Anderson, H.W.

Marking courses and hardwood silviculture seminars conducted at Bracebridge, Lindsay, Tweed and Sudbury.

Advisory role dealing with hardwood silviculture options (Blind River), Site Classification Methods (Algonquin Park).

Scientific authority on COFRDA Project 33012 - Post harvesting silvicultural techniques to enhance the white pine and red oak components in shallow site forests in Central Ontario.

Reviewer for O.R.R.R.G.P. Project GR-020-85 - Diversity and regenerative ability of plants in deciduous forests: effects of canopy openings.

Buchert, G.

Scientific Authority for COFRDA Project 33007 - Chemical characterization of jack pine as a contribution to developing genetic selection criteria for improving fibre production.

Scientific Authority for COFRDA Project 33017 - Seed development in jack pine.

Scientific Authority for COFRDA Project 33509 - The establish ment of isozyme gene markers for identification of important Hybrid poplar and clonal varieties.

Colombo, S.J.

Principal instructor, Container Update 1986: "Overwintering container stock." Nursery Managers course sponsored by Maritime Forest Ranger School, Fredericton, New Brunswick. 8-9 July 1986.

Technical presentation on Extended Greenhouse Culture and overwintering container stock. Extended Greenhouse Culture Techniques Seminar, Pineland Tree Nursery, Hadashville, Manitoba. 30 September 1986.

Glerum, C. and J. Paterson

Collaborated on chapter on Stand establishment under plantation evaluation in Managing Red Pine Plantations, OMNR 1986 publication.

Gordon, A.G.

Gave a lecture on "The sites, ecology, taxonomy, and hybridity of red and black spruce - aids in assigning environmental damage criteria in spruce-fir stands of New York and New England." Northeastern Forest Experiment Station, USDA Forest Service, Durham, NH. 10 December 1986.

Gave a seminar on "Spruce-fir forest stand dynamics and the effect of budworm perturbations." Geographical Inter-University Resource Management Seminars, Milton, Ont. 13 November 1986.

Ho, R.H.

Revieved a research proposal for Renewable Resource Research Grant program, MNR.

Reviewed a research proposal for National Sciences and Engineering Research Council of Canada. August 1986.

Reviewed a paper on "Accelerated Breeding: A Literature Review" by F. Schnekenburger, Fast Growing Forests, MNR, Brockville.

McClain, K.M.

Since September 1986, participated on the Steering Committee for the planning and design of the Northern Forest Biology Centre, a facility to be located at Lakehead University, which will accommodate both forestry and wildlife research activities. Research facilities will include state-of-the-art environmental growth rooms, project laboratories, computing facilities, resource centre, necropsy room and provision for a greenhouse complex. The location on the Lakehead University campus will provide a unique opportunity to interact with university research programs as well as to participate in undergraduate and graduate programs. Facilities are expected to be fully operational by the spring of 1989.

Odlum, K.D.

Technical presentations on: i) How to identify bud initiation and determine number of needle primordia in black spruce seedlings, and ii) Greenhouse temperature regimes for rapid bud initiation in black spruce. Extended Greenhouse Culture Techniques Seminar, Pineland Tree Nursery, Hadashville, Manitoba. 30 September 1986.

Odlum, K.D.

Technical guidance to Nor-Dev project #3062, assessing operational short-day bud initiation regimes at North Gro Development, Kenogami, Ontario.

Skeates, D.A.

An invitation was extended to participate in a program review conducted by the Canadian Forestry Service (CFS) at Petawawa. The review covered the work of all staff in the National Tree Seed Centre and included the seed bank, seed testing, seed storage studies, seed pathology and seed orchard production studies. A second review conducted at the Forest Pest Management Institute of the CFS in Sault Ste. Marie pertained to the early stages of a research program on cone and seed pests.

Stroempl, G.

In August, led a group of 32 management staff from the Algonquin and Central Regions on a field tour of OTIFBI's red oak experimental areas.

INTERNATIONAL DEVELOPMENT

Ho, R.H.

Supervisor for Tissue Culture Technicians in Training (CIDA program) - Sudarath Ngamkhajornwiwat and Chumnun Wongmanee of Thailand, July to September, 1986.

Skeates, D.A.

OTIFBI participated in training programs sponsored by CIDA in the field of seed and genetic resources. These related to the ASEAN/Canada Forest Tree Seed Centre project in Thailand. Seven foresters from South-east Asia participated in one of three programs, each of four months' duration, coordinated within the seed research program at Maple. The first program, with scientists from Thailand and the Philippines, related to seed testing in Sweden, Denmark and Petawawa, plus field visits in southern Ontario. The second, with scientists from Thailand, Indonesia and Malaysia, consisted mainly of seed studies and alternative production of genetic material. This included work in seed and stock production research at Maple plus a wide range of hands-on operational experience in provincial structures across Ontario. The third, with two Thai scientists, concentrated

on microtechnology at Maple. They worked primarily in the fields of isoenzymes and tissue culture, with visits to operational stations in southern Ontario.

In addition, as part of the ACFTSC program, OTIFBI participated in a study tour by Directors General of the ASEAN countries and/or their appointed scientists. Participants were from Brunei, Indonesia, Malaysia, Philippines, Singapore and Thailand.

A third component of Canadian participation consists of post graduate training in Canada. Five scientists from the ACFTSC visted Maple to review the seed research program here. Two have completed BSc studies at the University of Alberta, while three are enrolled in BSc/PhD programs at the University of British Columbia.

VISITORS TO MIDHURST AND MAPLE

A. Kubiske, Wisconsin
J. Iyer, Wisconsin
W. Rietveld, Wisconsin
W. Botti, Michigan
W. Schroeder, PFRA, Saskatchewan
W. Kayler, Newfoundland
R.D. Hallett, Canadian Forestry Service, Maritimes Forest Research Centre, Fredericton, New Brunswick
G. Dunsworth, MacMillan-Bloedel Research Division, Nanaimo, B.C.

PUBLICATIONS

BATES, D. and D. GILLMEISTER. (Eds.) Ontario Tree Improvement and Forest Biomass Publications 1980-1985 (An Annotated Bibliography). OMNR For. Res. Rep. No. 114. 31 p.

BUCHERT, G.P. Forest genetics and tree improvement research at Maple: 1983-1985. In Proc. 20th Meeting Can. Tree Improvement Assoc., Part 1. Quebec, 19-22 Aug. 1985. pp. 109-111.

BURGER, D. Physiography as an integral part of forest ecosystems. In Proc. Int. Symp. Forest Ecocyst. Manag. & Envir. Protection. Antu, Jilin Prov., P.R.C., 5-11 June 1986.

COLOMBO, S.J. Second-year shoot development in black spruce Picea mariana (Mill.) B.S.P. container seedlings. Can. J. For. Res. 16(1): 68-73.

COLOMBO, S.J. and (R.C. CAMERON). Assessing readiness of black spruce container seedlings for frozen storage using electrical impedance, oscilloscope square wave and frost hardiness techniques. OMNR For. Res. Note No. 42. 6 p.

GLERUM, C. Some physiological aspects of plantation establish ment. In Proc. Northwestern Region Silviculture Information Session, Kenora, Ont., 17-19 Mar. 1985. 11 p.

GORDON, A.G. Breeding, genetics and genecological studies in spruce for tree improvement in 1983 and 1984, Sault Ste. Marie, Ont. In Proc. 20th Meeting Can. Tree Improvement Assoc., Part 1. Quebec, 19-22 Aug. 1985. pp. 112-116.

GORDON, A.G. The potential impact of the long-range transport of air pollutants on Canadian forests. G.A. Fraser et al., Inf. Rep. E-X-36, Can. Forestry Service, Ottawa. 43 p.

HO,R.H. Micropropagation of American elm. In New Ways in Forest Genetics. F. Caron, A.G. Corriveau and T.J.B. Boyle (Eds.). Proc. 20th Meeting Can. Tree Improvement Assoc., Part 2. Quebec, 19-22 Aug. 1985. pp. 78-82.

HO,R.H. Cone induction in white and Norway spruce. In New Ways in Forest Genetics. F. Caron, A.G. Corriveau and T.J.B. Boyle (Eds.). Proc. 20th Meeting Can. Tree Improvement Assoc., Part 2. Quebec, 19-22 Aug. 1985. pp. 96-102.

HO, R.H. Cone induction and in vitro culture in some forest tree species. In Proc. 20th Meeting Can. Tree Improvement Assoc., Part 1. Quebec, 19-22 Aug. 1985. pp. 120-123.

KIM, Y.T. and R.H. LEECH. The potential use of DRIS in fertilizing hybrid poplar. Commun. in Soil Sci. Plant Anal. 17(4): 429-438.

(KOBMOO, B.) and D.A. SKEATES. X-radiography of tropical forest tree seed. ASEAN-Canada Forest Tree Seed Centre, Muak Lek, Saraburi, Thailand. The Embryon 2(1): 49-55.

LARSSON, H.C. Ontario lowland trees. OMNR/OTIFBI File Report. 39 p.

MacDONALD, G.B. and R.R. FORSLUND. Application of a geometrical volume equation to species with different bole forms. Can. J. For. Res 16(2): 311-314.

MAURER, N.L., G.D. RACEY and R.E. HUTCHISON. The Dunemann option: small scale production of tree seedlings. OMNR For. Res. Rep. No. 113. 14 p. + appendices.

McCLAIN, K.M. Water relations and associated morphology of conditioned Douglas fir and jack pine seedlings subjected to periods of drought stress. Submitted in partial fulfillment of requirements for the degree of Ph.D., Oregon State University, 20 Feb. 1986.

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STAFF CHANGES

After seven years in OTIFBI's administrative office, Barbara Morrell has transferred to a position in the Maple District Office.

Karina Bates joined our permanent staff as Purchasing and Accounts Clerk after working on contract in various aspects of administration.

Joan Wild left the Tree Improvement Unit in June to work with MNR in Sudbury as Regional Tree Improvement Specialist for the Northeastern Region.

Liz Scott left the Soils Lab to finish her flight training, and is now a single-engine flying instructor at the Brampton Flying Club.

Larry Daisley left the Forest Genetics Section of the Tree Improvement Unit in August to take a teaching position at Seneca College.

Kim Roberts left the Biomass Unit to practice forestry in the private sector. After some years on contract, Jim Rice joined Harvey Anderson's Tolerant Hardwood Group as the Data Analyst.

In October, Diana Callaghan (nee Morgan) was seconded to MNR's Forest Resources Group Program Planning and Budget Section as an Acting Group Advisor.

In December 1985, Frank Matejka left the Pest Control Section at Maple to become our Systems Specialist at OTIFBI, replacing John Boufford who had been transferred to Systems Services in Toronto.

In late 1985, the field unit at Dorset was disbanded. Mac MacLean is continuing his research on secondment to the Algonquin Regional Office, while William Ohlmann was seconded to the Bracebridge District Office.

ONTARIO TREE IMPROVEMENT AND FOREST BIOMASS INSTITUTE

D.P. Drysdale - General Manager
P. Mueller Secretary

Administrative Support Unit

M. Johnstone
J. Kucopy
D. Watson
K. Bates

Technology Transfer

D. Bates - Technology Transfer Specialist
D. Gillmeister +
J. Robinson

Systems Support

F. Matejka **

Tree Improvement and Biomass Section

G. Buchert - Principal Scientist
S. Brenham (Secretary)

Forest Biomass Unit

H. Anderson (Leader)
J. Rice
W. Beekers
P. Ntayombya +
P. Jaciw
A. Herzan +
D. Weingartner

Tree Improvement Unit

G. Buchert (Leader)
M. Weishar
J. Winters +
T. Taylor
K. Gashoka *
K. Fischer *
L. Farintosh +
C. Papadopol *
D. Skeates
D. Irving
R. Ho
Y. Raj *
M. Baird *
O. Hak +
K. Sweeting +
A. Gordon
N. Jondreau
N. Lussier
S. Loeppky +
M. Famiglietti
A.J. Mosseler *

Nursery/Greenhouse/ Arboreta Unit

K. Bennett (Leader)
D. Gamble
J. Byrnes
F. Mestyan +
M.A. Pratchett +
S. Taylor +

Forest Ecology and Silviculture Section

D. Burger - Principal Scientist
J. Tonge (Secretary)

Site and Productivity Unit

D. Burger (Leader)
L. Spence
L. Packer +
J. Nightingale +
A. Curtis +
M. Connors +
G.B. MacDonald
D. Morris *
L. Kapron +

Silviculture and Tree Biology Unit

C. Glerum (Leader)
J. Paterson
Y.T. Kim
C.P. Chen
D. Hickie *
L. Spence (Mrs) +
G. Stroempl
G. Racey *
R. Hutchison
S. Colombo
K. Odlum *
R. Koppenaal *
S. Spezzaferro +
P. Menes +
R. Betts +
A. Jagodits +
N. Vanhinsberg +
K. McClain
T. Casella
N. Knudsen
R. Forslund
G. Robinson

* Long-term Contract Positions
** Systems Services, Toronto
\+ Seasonal

M.M. McLean - seconded, Algonquin Region
W. Ohlmann - seconded, Bracebridge District

as of December 31, 1986